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OVERVIEW ENVIRONMENTAL ASSESSMENT
OF
FOUR POTENTIAL RESERVOIR DEVELOPMENTS
ON WILLOW CREEK, ALBERTA

February 1986

DDN 7194947

OVERVIEW ENVIRONMENTAL ASSESSMENT
OF
FOUR POTENTIAL RESERVOIR DEVELOPMENTS
ON WILLOW CREEK, ALBERTA

by

LGL Limited
environmental research associates

in association with
Aquatic Environments Ltd.,
Fedirchuk McCullough & Associates Ltd.,
HydroQual Consultants Inc.,
Intera Technologies Ltd.

Prepared for

Alberta Environment
Planning Division

February, 1986

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EXECUTIVE SUMMARY

Alberta Environment is currently assessing the feasibility of developing a water storage reservoir at one of four potential sites in the Willow Creek basin. To aid in site evaluation and selection, Alberta Environment retained LGL Ltd., in association with Aquatic Environments Ltd., Intera Technologies Ltd., Fedirchuk McCullough and Associates Ltd., and HydroQual Consultants Inc., to conduct an overview assessment of wildlife, fisheries, geology, soils, land use, historical, and water quality issues at the four sites.

Wildlife

From a wildlife perspective, the four sites were assessed, based on known utilization by wildlife and habitat potential. Site 1 (Willow Creek) encompasses key mule deer and white-tailed deer range and provides moderate quality habitat for the majority of terrestrial and aquatic species found in the area. It was rated second in vulnerability to project-related impacts. Site 2 (Pine Coulee) supports no known concentrations of important wildlife species and has low habitat capability for most wildlife because of a lack of suitable shrub or forest cover and stream habitat. It has been rated least vulnerable to project impacts. Site 3 (Kuntz Creek/Willow Creek) is immediately adjacent to important ungulate ranges and supports high quality habitat for both terrestrial and aquatic wildlife. Consequently, it has been rated most vulnerable to project impacts of the four sites. Site 4 (Pine Coulee/Willow Creek) encompasses the northern extent of a key mule deer and white-tailed deer range, an active heron colony and a potential viable pheasant population. Portions of Willow Creek to be flooded support moderately high quality food and cover sources for the majority of wildlife in the area. This site has been ranked second in vulnerability to project impacts, similar to Site 1.

Fisheries

From a fisheries perspective, the four reservoir developments were evaluated, based on their projected impacts on existing fisheries, and their potential for creating new fisheries. Willow Creek at Sites 1 and 4 currently supports cool water fish species (pike, burbot, suckers, other forage species and possibly white fish). Dam construction at these sites would alter upstream habitat, could stabilize downstream flows and habitat, and could block up and downstream migrations of these species. Site 2, because of the intermittent nature of Pine Creek, has virtually no current fisheries potential and, consequently, its dam would not obstruct fish movements or alter important existing habitat. The low-head diversion weir to be constructed on Willow Creek to divert water to Pine Coulee is not expected to create a fish blockage, particularly, if equipped with a fish ladder. Site 3 (Kuntz Creek/Willow Creek) supports both trout and cool water species. Reservoir development at this site would inundate moderately good quality stream habitat and could present an obstacle to fish migration.

Based on information from other comparable reservoirs in the province, it is anticipated that cool water species (i.e., pike, burbot, suckers) will, in the long term, dominate any reservoir created in the Willow Creek basin. Because high flushing rates and low morphoedaphic indices are projected for reservoirs created at Sites 1 and 3, these reservoirs would produce the least productive fisheries of the four sites. The large water storage area in Pine Coulee, which is common to both Sites 2 and 4, would have a low turnover rate and more suitable morphology for fish production. Consequently, these two sites are considered to have greater potential as a reservoir fishery.

Geology, Soils, Land Use

Available data suggests that the geology of the study area generally consists of Tertiary and Cretaceous sandstones and shale of the Willow Creek, Paskapoo and/or Porcupine Hills Formations. Soils generally have developed on glacial till, glacio-fluvial or fluvial sediments, and are predominantly of the Chernozermic, Regosolic, Luvisolic, Brunsolic and Gleysolic orders.

Based on Land Systems identified for each of the sites, Site 2 has the least potential for erosion problems, given project development. Characterized by moderately-sloped valley sides, this area has almost no active surface erosion. Two saline sloughs on adjacent uplands could present reclamation problems if disturbed during construction.

Sites 1 and 4 both are characterized by localized, steep slopes along Willow Creek, with some active surface erosion being evident. They offer slightly greater potential for surface erosion and reservoir sedimentation than Site 2. Small localized saline sloughs near Site 1 present potential although minor reclamation problems, if disturbed during construction.

Because of its steep-walled topography, Site 3 has the greatest potential for surface erosion adjacent to the reservoir. Project-related erosion on dry, steep slopes with shallow soils could also present reclamation problems.

Flooding as a result of dam site construction would predominantly affect private lands and agricultural activity at all four potential sites. Site 4 development would result in the largest area of bottomland being inundated, followed by Site 1, Site 2, and Site 3, in that order. The flooding of Site 4 would also result in the loss of the Willow Creek Provincial Park.

Historic Resources

From a historic resources perspective, the four sites were evaluated, based on their known historic, prehistoric and palaeontological significance and their potential for harbouring as yet undetected historical resources. To date, information collected from within the four reservoir areas represents mere inventory data and the sites have not been assessed for their local and regional significance. At Site 1, 29 prehistoric sites have been identified within the projected full supply level (F.S.L.) of the reservoir, ranging from isolated finds to bison kill complexes, and further detailed studies should reveal additional sites. This site also harbours the historic Leavings site complex and some of the best palaeontological exposures of both the Willow Creek and Porcupine Hills formation. The combined prehistorical, historical and palaeontological potential of this site makes it most vulnerable to project impacts, relative to the other reservoir sites.

There are few recorded historic and prehistoric sites identified within the F.S.L. of Site 2, although this site potentially does have deeply buried prehistoric sites. Pine Coulee was noted for harbouring illegal whiskey traders frequently pursued by the Northwest Mounted Police and significant historic sites related to this theme as well as early ranching, may also be present. There is, however, little potential for significant palaeontological sites in the area. This site has been ranked lowest in overall vulnerability to project impacts, relative to the other sites.

Although no prehistoric and historic finds have been identified to date on Site 3, this area has a moderately high potential of harbouring such sites, since it represents the continuation of a restricted settlement/activity corridor along Willow Creek into the Porcupine Hills. However, limited bedrock exposures of palaeontological significance occur at this site, and it has been ranked third in overall vulnerability to project impacts.

Site 4 has moderately high prehistoric, historic and palaeontological significance along that portion of Willow Creek to be inundated. Because of the presence of a large outcrop of Porcupine Hills Formation, the Oxley Ranch Headquarters Site and terrain suitable for prehistoric activities, this site has been ranked second only to Site 1 in vulnerability to project impacts.

Water Quality

When not experiencing drought conditions, the reach of Willow Creek from Chain Lakes to Claresholm supports good to very good water quality, with relatively few parameters consistently exceeding the Alberta Surface Water Quality Objectives. From a water quality perspective, reservoirs developed at Sites 1 and 3 would be preferable to the two offstream Pine Coulee locations. The shallower mean depth and lower flushing rates of reservoirs at Sites 2 and 4 will likely result in mesotrophic to eutrophic conditions, increased plant and algal growth and reduced water clarity. Because of the less favourable trophic status of Sites 2 and 4, some bottom water oxygen deficits may result during the winter at these sites.

All sites will experience an initial trophic upsurge during reservoir formation, and downstream taste and odour problems in drinking water may result. This will be a short-lived problem for Sites 1 and 3, because of high onstream flushing rates, but could be more prolonged for Sites 2 and 4.

Elevated summer streamflows resulting from water release from any of the proposed reservoirs should prevent poor downstream water quality conditions currently experienced in Willow Creek during drought conditions. Existing winter water quality should not be appreciably altered by water release from any of the reservoir sites.

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1. INTRODUCTION

The Willow Creek Basin has historically experienced occasional spring flooding and more regular late summer and winter water shortages. To stabilize water supplies within the basin, the Prairie Farm Rehabilitation Association (PFRA) developed the Chain Lakes Reservoir, located in the upper end of the Willow Creek drainage. Completed in 1962, the reservoir's 17,000 acre-foot capacity adequately met the recreational, municipal and agricultural demands placed on it. However, since that time, water demands have grown significantly, and Willow Creek is once again an unreliable water source. In fact, the creek experienced a freeze-up during the winter of 1982 and near dry conditions during the summer drought of 1984. With future increases in water demands from municipal and industrial development being projected for the area, the question of water supply becomes even more unclear.

To rectify this inevitable problem, Alberta Environment is now investigating the feasibility of constructing one or more additional water storage sites within the Willow Creek Basin. When studies were first initiated in 1982, 23 potential sites were identified on 1:50,000 scale NTS maps. Based on hydrological, geological, topographical and land use issues, only six of the 23 sites were selected for detailed evaluation (Klohn Leonoff 1984). Currently, three of those six are being considered as potential sites, in addition to a fourth site which was recently proposed by the Willow Creek advisory committee (July 1985).

LGL Ltd., in association with Aquatic Environments Ltd., Intera Technologies Ltd., Fedirchuk McCullough and Associates Ltd., and HydroQual Consultants Inc. was retained by Alberta Environment, Planning Division to: i) conduct an overview assessment of wildlife, fisheries, geology, soils, land use, historical resources and water quality for the four potential storage sites; ii) identify significant data gaps in the resource information; and iii) assess the pertinent environmental issues related to the four areas. This study relied primarily on existing data sources for assessment purposes, and no extensive field work was undertaken.

In addition to addressing the above mentioned tasks, investigations into local concerns surrounding the reservoir development were also to be undertaken. Local concerns were to be identified and summarized through a series of land owner interviews. At the time of this reports' preparation, the interviews had just been completed. Consequently, details on the format and results of this study component will be presented under separate cover at a later date.

2. STUDY OBJECTIVES

The primary objective of this study was to provide an overview assessment of resources in the vicinity of four potential water storage sites in the Willow Creek Basin. This objective was fulfilled through the completion of discipline-specific tasks, as identified in the study's Terms of Reference. These tasks or study "component requirements" are restated in the appropriate section developed below for each of the study disciplines.

3. STUDY AREA

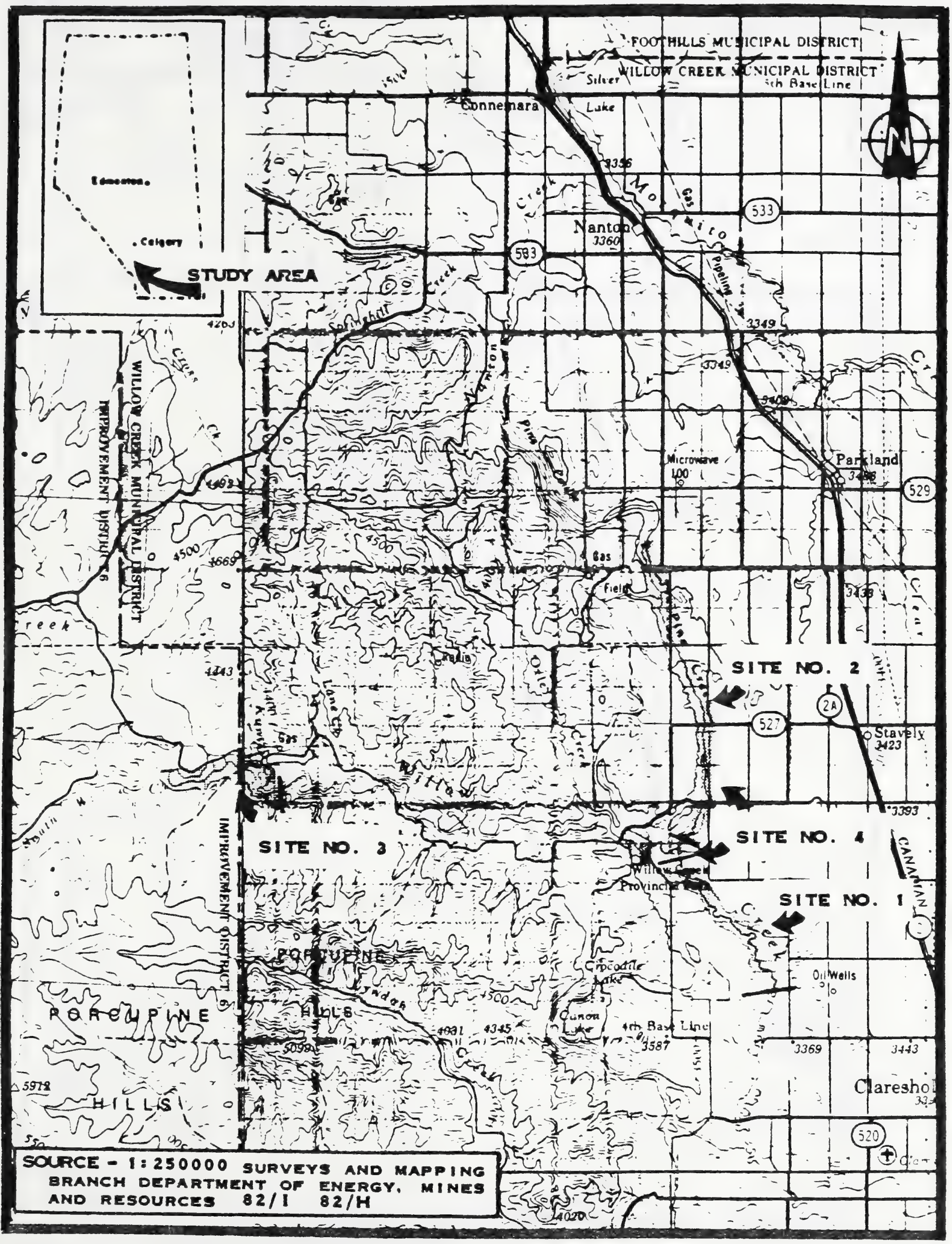
As previously discussed, four sites within the Willow Creek Basin are currently being considered for water storage. For the purposes of this study, these sites are referred to as:

1. Willow Creek
2. Pine Coulee
3. Kuntz Creek/Willow Creek
4. Pine Coulee/Willow Creek

These sites are situated on Willow and Pine Creeks along the eastern perimeter of the Porcupine Hills (Figure 3-1). During the height of the last glaciation, Laurentide ice flanked the Porcupine Hills, with only those areas above 1,700 meters escaping continental glaciation. Willow Creek and Pine Creek, misfit streams, occupy glacial meltwater channels. Although the Willow Creek meltwater channel is related to the last glaciation, the morphology of Pine Coulee, primarily the extent of colluviation observed, suggests that this meltwater channel may relate to earlier glacial episodes (L. Hills (Fedirchuk McCullough), personal communications).

Site No. 1, Willow Creek near Claresholm, is located in Sections 12, 13, 14, 15, 22, 23, 24 and 27, Township 13, Range 28, West of the 4th Meridian (Figure 3-2). It is situated on the eastern edge of the Porcupine Hills and falls within the Mixed Grass Ecoregion of Alberta (Strong and Leggat 1981). This potential reservoir site is characterized by steep valley walls primarily along its western edge, extensive bedrock outcrops, and a forest and shrub-dominated valley bottom. Well developed terraces occur along both flanks of the creek.

Site No. 2, Pine Coulee, is located in Section 34, Township 13, Range 28, West of the 4th Meridian; Sections 2, 3, 10, 15, 22, 28, and 33, Township 14, Range 28, West of the 4th Meridian; and Section 3, Township 15, Range 28, West of the 4th Meridian (Figure 3-3). Also falling within the Mixed Grass Ecoregion, Pine Coulee is a broad treeless valley through which an intermittent creek flows. A number



SOURCE - 1:250000 SURVEYS AND MAPPING BRANCH DEPARTMENT OF ENERGY, MINES AND RESOURCES 82/I 82/H

Figure 3-1 LOCATION OF STUDY AREA

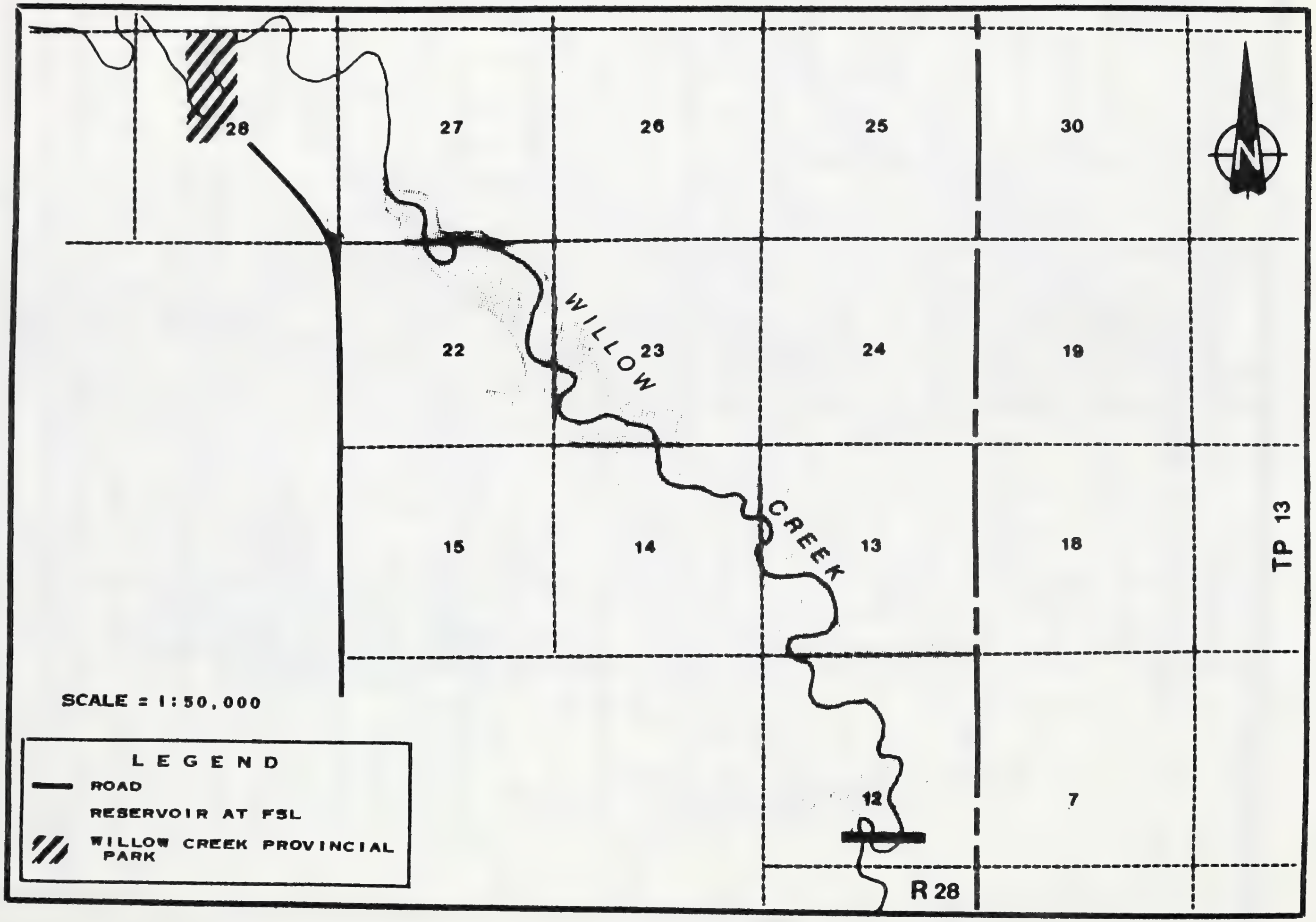


Figure 3-2. Site No. 1, Showing extent of reservoir at full supply level (after Klohn Leonoff Ltd. 1984).

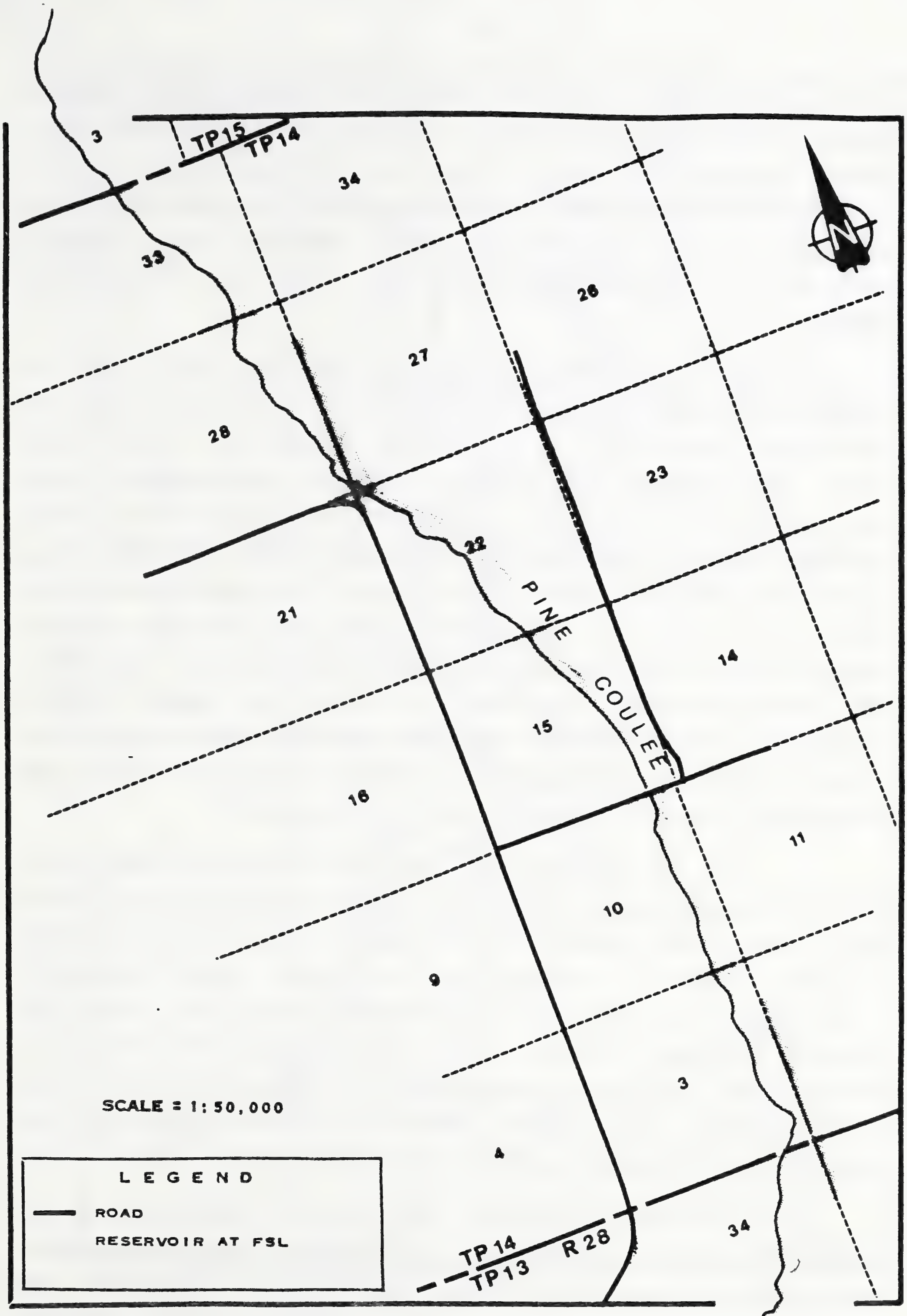


Figure 3-3 SITE NO. 2, SHOWING EXTENT OF RESERVOIR AT FULL SUPPLY LEVEL (after Klohn Leonoff Ltd. 1984)

of tributaries join the creek along the length of the proposed reservoir site and intermittent saline ponds occur on the valley floor. Most of the floor of Pine Coulee has been broken and is currently used for pasture. Colluvial activity in Pine Coulee has resulted in gently sloping valley walls. The few bedrock outcrops which do occur are generally restricted to the east side of the coulee.

Site No. 3, Willow Creek near Lane Creek/Kuntz Creek, is located in Sections 1, 2 and 11, Township 14, Range 30, West of the 4th Meridan and Sections 1, 2, 11 and 12, Township 14, Range 1, West of the 5th Meridian (Figure 3-4). Situated approximately 20 km upstream of Pine Coulee, this site consists of a narrow valley flanked by rugged foothills topography. Within the defined reservoir area, Kuntz Creek flows into Willow Creek from the north and Johnson Creek and McIntosh Creek from the south. Some well developed terraces occur, primarily along the north side of Willow Creek. Falling within the Fescue Grassland Ecoregion of Strong and Leggatt (1981), grasslands characterize the north bank whereas discontinuous mixed forests characterize the south bank. Bedrock outcrops are limited and are primarily exposed in deeply incised valley walls.

Site No. 4, near the Willow Creek-Pine Coulee confluence, involves the impoundment of both Pine Coulee and Willow Creek (Figure 3-5). Under this scenario, the Pine Coulee reservoir, as described for Site 2, would be extended south to Willow Creek. Additional flooding on Willow Creek would occur in Sections 27, 28, 32 and 33, Township 13, Range 28, West of the 4th Meridian. This portion of Willow Creek is similar biophysically to Site 1, possessing forest and shrub dominated valley floor communities, steep valley walls and adjacent well developed, pasture or grass dominated terrains.

Prior to the start of the study, it was recognized that reservoir locations, as identified in the study's Terms of Reference, were tentative, based on preliminary engineering considerations, and that detailed engineering design (i.e. forebay levels, drawdown

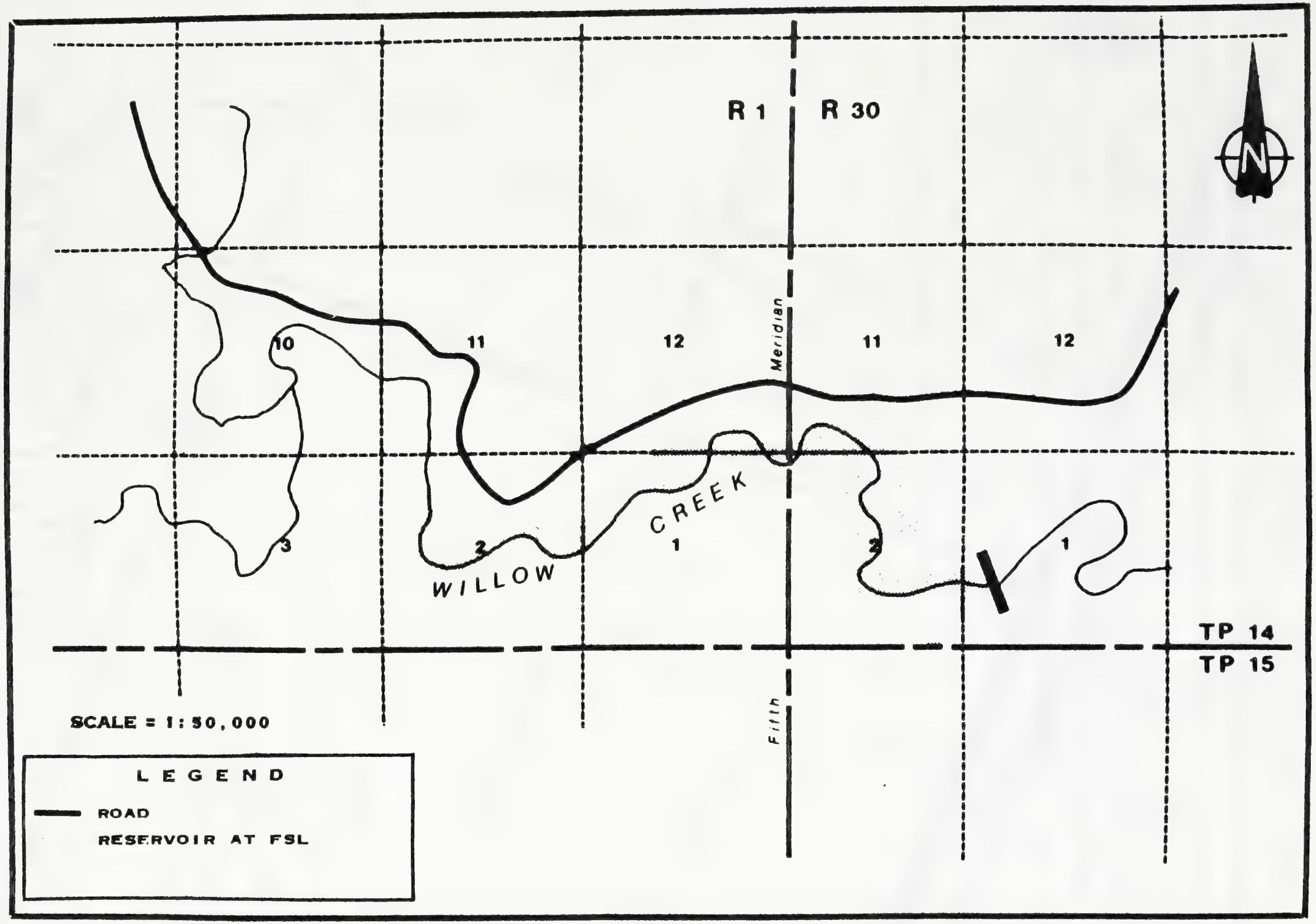


Figure 3-4 SITE NO. 3, SHOWING EXTENT OF RESERVOIR AT FULL SUPPLY LEVEL (after Klohn Leonoff Ltd. 1984)

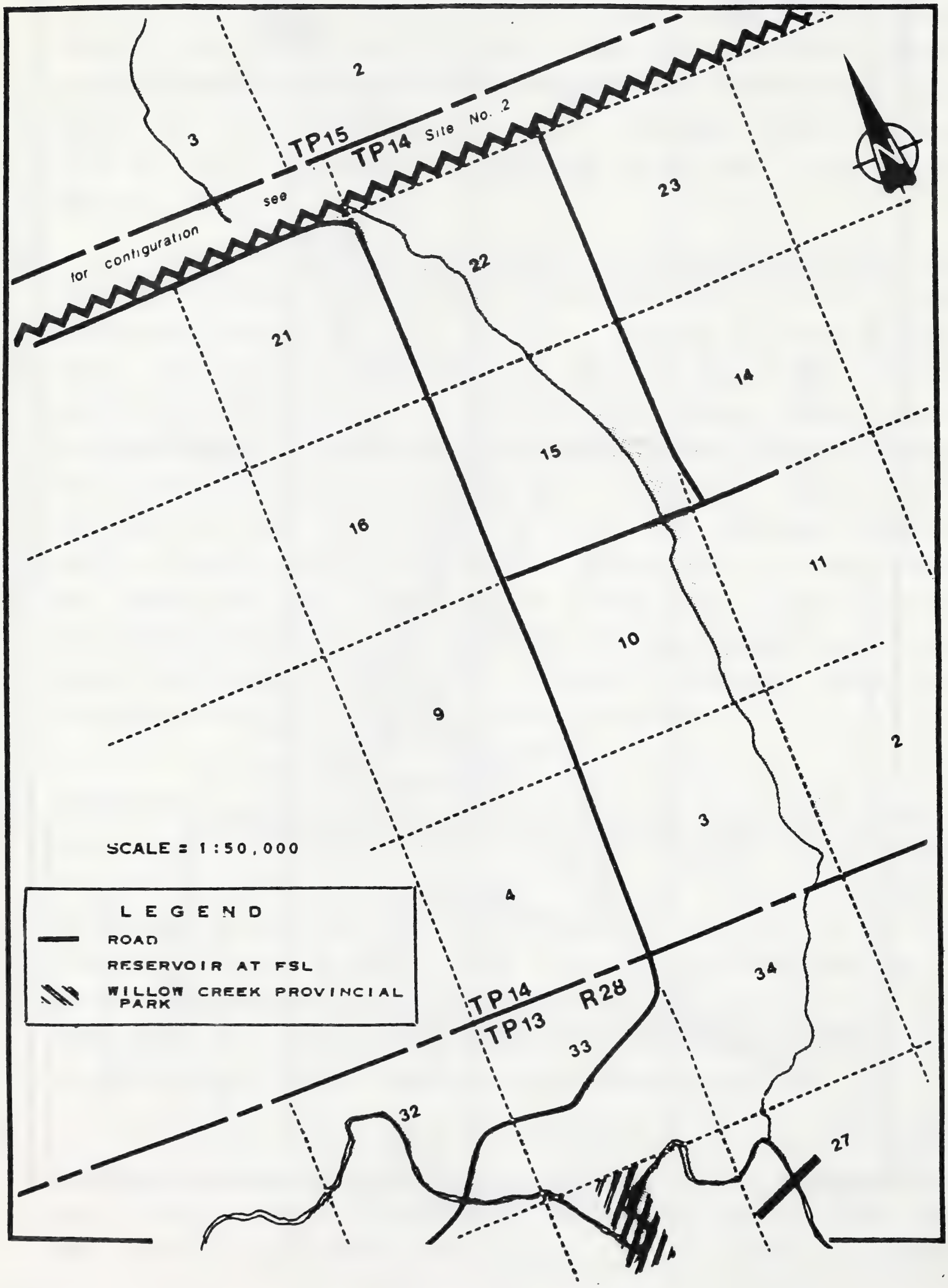


Figure 3-5. SITE NO. 4, SHOWING EXTENT OF RESERVOIR AT FULL SUPPLY LEVEL (adapted from Klohn Leonoff Ltd. 1984).

scenarios, etc.) had yet to be undertaken. Consequently, it was decided that all lands falling within 1.0 km of the designated reservoirs would be included in the overview assessment of resource values, and that the evaluation of geology, soils, land use, historical resource potential and wildlife and fisheries habitat would extend at least to this limit. This inclusion of additional surrounding lands ensures that future impact assessment can be undertaken for a variety of forebay scenarios and a variety of ancillary facilities (i.e. borrow sites, campsites, etc.) which may be temporarily located adjacent to the dam sites.

4.0 WILDLIFE

4.1 COMPONENT REQUIREMENTS (from study Terms of Reference)

1. Assess current wildlife utilization of the sites.

2. Describe and map the wildlife habitat of the sites; emphasis should be on elk, moose, deer, colonial nesters, upland game birds, waterfowl, furbearers and any rare or unique species. Existing habitat quantity and quality and factors limiting capability of the area should be included.

3. Compare the value of the three sites to wildlife within the basin and the region.

4.2 APPROACH AND RATIONALE

To assess the significance of any given area for wildlife, both population and habitat data can be utilized. The use of population data assumes that an area's importance to wildlife is reflected by the relative abundance of animals present and, hence, requires adequate census data. Such an approach has two major shortcomings:

1. Adequate census data are frequently not available and are expensive and difficult to collect; and

2. An area's wildlife population may be unusually low at any given point in time due to human disturbance, predation, short-term climatic factors, or natural demographic cycles. Consequently, animal numbers alone may not adequately reflect an area's potential importance to wildlife.

A habitat approach assumes that selected biophysical conditions (e.g., vegetation, aspect, relief, etc.) can be utilized to assess an area's suitability for wildlife. Such an approach relies primarily on the quantification or evaluation of selected biophysical conditions or parameters within the area of interest which are known to be related to wildlife capability. Since biophysical data are less expensive to obtain and less time-specific than population data, a habitat-based approach is generally better suited for overview assessments of wildlife resources.

For the purposes of this study, both data sources were utilized. Available population data for the four areas were reviewed to assess known utilization, but were not used as the major comparative data base for evaluating the relative importance of the sites. Instead, biophysical data drawn from available air photo coverage were used to evaluate and quantify wildlife habitat in each of the proposed sites, and habitat capability was used as the predominant parameter to compare reservoirs from a wildlife perspective.

4.3 METHODS

4.3.1 Selection of Study Species

Because a large number of wildlife species potentially inhabit the four storage areas, it was impractical to consider all of these species in evaluating the importance of proposed sites. Generally, for studies of this nature, key or "evaluation" species are selected for consideration. These species are of particular socio-economic or ecological significance and, in many cases, adequately represent the habitat requirements of a variety of other species. In the study's Terms of Reference, it was suggested that study emphasis be directed towards elk, moose, deer, colonial nesters, upland game birds, waterfowl, furbearers and any rare or unique species. More specifically, we selected elk, moose, mule deer, great blue heron, pheasant, mallard, beaver and snowshoe hare for the following reasons:

elk and moose - as requested;

mule deer - because of its affinity for the relief and vegetative cover provided by watercourses, particularly in agricultural areas, and because of its predominance in the area, relative to white-tailed deer;

great blue heron (as a colonial nester) - because of its affinity for water courses and its relatively common occurrence in the area;

pheasant (as an upland game bird) - because of its affinity for riparian cover within agricultural lands;

mallard (a representative waterfowl species) - because of its use of small ponds and streams, particularly in spring during the breeding season;

beaver - as a representative semi-aquatic furbearer which is highly dependent on wetlands and streams;

snowshoe hare - as a representative terrestrial furbearer, highly dependent on vegetative cover such as riparian stands. Because of the hare's importance as a prey base item, any evaluation of habitat suitability for hare will also be somewhat applicable to several small to medium sized carnivores.

It is these species for which habitat evaluation models were developed, a topic discussed in greater detail below.

It should be noted that many species of wildlife have relatively different habitat requirements on a seasonal basis, and seasonally-specific habitat evaluation models are frequently developed for them. However, for this comparative overview of wildlife resources within the four study regions, habitat evaluation models were only prepared for that season of the year when habitat availability is considered most limiting. Consequently, for mule deer, elk, and moose, only the fall/winter period has been considered in the evaluation process. Year-round models have been prepared for the remaining species, which demonstrate minimal seasonal changes in their habitat requirements.

4.3.2 Assessment of Current Wildlife Utilization of the Proposed Sites

As previously discussed, wildlife abundance and distribution data were not used as the major comparative data base for wildlife concerns within the four potential storage sites. However, such information was reviewed to determine current wildlife use patterns and to attempt to delineate particularly important habitat components such as mineral licks, commonly used nesting or reproductive sites, etc., which could not be identified based on a biophysical assessment alone. The data were assembled from Alberta Fish and Wildlife Division (AFWD) reports and key area maps in Lethbridge, interviews with AFWD personnel, local landowners and others familiar with the area, and a brief aerial and ground reconnaissance conducted 14 June, 1985. Canada Land Inventory maps also were consulted for an independent assessment of capability for ungulate and waterfowl production.

4.3.3 Development of Habitat Suitability Index (HSI) Models

A variety of habitat evaluation models are currently being utilized within the province to provide valid, cost-effective assessments of wildlife capabilities (IEC Beak 1984; Green et al. in prep.; LGL 1985). For this study, we developed models similar in format and mechanics to those used for the Inventory of Alberta Drainage Requirements Program (Green et al. in prep.), currently being conducted for Alberta Environment. However, the biophysical parameters considered in the models were altered considerably from those used in the drainage program because of the nature of the habitat being evaluated.

In general, two types of models were developed for each storage site, one for terrestrial wildlife species being considered (i.e. elk, mule deer, moose, pheasant, hare) and one for those species being more dependent on the watercourse itself (i.e. beaver, mallard, heron). In each case, model development entailed the completion of three basic steps:

1) the final selection of habitat variables (and appropriate variable categories) considered to significantly influence habitat suitability for each evaluation species;

2) the development of relationships or ranking systems which numerically relate habitat variable categories to habitat suitability for each evaluation species;

3) the mapping and quantification of habitats to be evaluated by the HSI models.

Step 1

Biophysical variables used for evaluation purposes were selected based on their ability to influence habitat suitability and to be evaluated from remotely sensed data sources. A biophysical map of the study areas was developed by Intera Technologies Ltd. (see Section 6.0) which divided each of the potential reservoir sites into Land Systems, based on geomorphology, landform, slope, surface expression and aspect (see map pocket on back cover of report). These Land Systems were, in turn, subdivided by vegetative cover, soil and drainage characteristics into Land Types. In addition to these variables, stream permanency and stream sinuosity were also considered as habitat evaluators but were not mapped. Each of these ten biophysical variables were broken down into fixed classification categories which identified, in a general way, the full range of conditions occurring in the region. For example, such categories as bare rock, coniferous trees, deciduous trees, shrub meadow, etc. were recognized for the biophysical variable "ground cover". Similarly, aspect categories included "flat, north (W-N-SE) and south (SE-S-W). For the purposes of model development, only ground cover, slope, aspect, stream sinuosity, and stream permanency were considered to be significant habitat evaluators and incorporated as model components.

Step 2

The relationships or ranking systems used to relate habitat variable categories to habitat suitability were subjectively developed, based on the known habitat preferences and requirements of the species of interest. Each variable category was assigned a ranking value which reflects the relative ability of that category to provide a life requisite of the species in question. In general, food and cover were the life requisites considered in the habitat evaluation models.

Figure 4-1 demonstrates the format and ranking system of the habitat evaluation models, using mule deer as an example. In this model, food and cover are considered to be the major life requisites influencing the abundance of this species. As previously discussed, the model pertains to the fall/winter period only, when habitat is most limited for this species.

In fall/winter, the ability of a Land System to provide cover is considered to be directly influenced by the ground cover present, in addition to slope and aspect. Ground cover and aspect are, in turn, considered to influence the availability of food. Associated with each of these selected variables is a weighting factor which reflects the relative importance of that variable in providing the life requisite in question. For the cover variables, ground cover is considered to be the most significant variable, with aspect and slope being of secondary importance. For food, ground cover and aspect are considered to be of comparable importance and are weighted accordingly.

Several categories are identified for each habitat variable, and a suitability rating is assigned to each, ranging in value from 0 (inadequate) to 3 (optimal). As previously discussed, these values reflect the relative ability of each category to provide the life requisite in question. To determine the overall habitat suitability rating (HSR) of a given land system, the variable category which best describes conditions within the area is selected for each habitat

Figure 4-1. Willow Creek Wildlife Capability Model - Mule Deer

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Fall/ Winter	0.6	Cover	0.6	Cover type	0	-bare soil/rock
					1	-seasonal wetland
					1	-permanent wetland/ open water
					0	-native grassland
					0	-improved pasture
					0	-cropland
					1	-shrub meadow (10-50% shrub cover)
					2	-shrubland (>50% shrub cover)
					2	-conifer parkland (10-50% tree cover)
					1	-deciduous parkland
					3	-conifer forest (>50% tree cover)
					2	-deciduous forest (>50% tree cover)
					2	-mixed forest (>50% tree cover)
			0.2	Slope characteristics	3	-steep, broken (>30° slopes predominate)
					2	-moderate, rolling (10-30°)
					1	-flat (<10°)
			0.2	Major aspects	1	-cool slopes (W-N-SE)
					3	-warm slopes (SE-S-W)
					1	-flat
			N/A	Stream permanency		-intermittent
						-permanent
			N/A	Stream sinuosity		-straight
						-curved
						-meandering

Figure 4-1. (cont'd) Willow Creek Wildlife Capability Model - Mule Deer

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Fall/ Winter	0.4	Food	0.6	Cover type	0	-bare soil/rock
					1	-seasonal wetland
					1	-permanent wetland/ open water
					1	-native grassland
					1	-improved pasture
					1	-cropland
					2	-shrub meadow (10-50% shrub cover)
					3	-shrubland (>50% shrub cover)
					1	-conifer parkland (10-50% tree cover)
					2	-deciduous parkland
					1	-conifer forest (>50% tree cover)
					3	-deciduous forest (>50% tree cover)
					2	-mixed forest (>50% tree cover)
			N/A	Slope characteristics		-steep, broken (>30° slopes predominate)
						-moderate, rolling (10-30°)
						-flat (<10°)
			0.4	Major aspect	1	-cool slopes (W-N-SE)
					3	-warm slopes (SE-S-W)
					2	-flat
			N/A	Stream permanency		-intermittent
						-permanent
			N/A	Stream sinuosity		-straight
						-curved
						-meandering

variable being considered. (In the case of ground cover, when several categories may occur in a Land System, each cover type is considered and weighted, based on the proportion of the Land System it comprises). The suitability rating (SR) value assigned to the selected category is then multiplied by the appropriate weighting factor for that variable. Where several variables are involved for a given life requisite, these products are summed, providing a seasonal habitat suitability rating (HSR). To produce a habitat suitability index (HSI) ranging in value from 0 to 1 to facilitate habitat unit calculations (see Section 4.3.4 below), this HSR value is, in turn, divided by 3.

In Appendix I, a description of major habitat requirements and resulting model assumptions and format are presented for each species. Actual formulae for the calculation of habitat suitability indices (HSI's) are also provided. It should be noted that a detailed literature review has not been developed to rationalize the selection of habitat evaluators. Instead, the reader is referred to several extensive documents on wildlife-habitat relationships which have recently been prepared for independent studies (Brechtel 1981, Green et al. 1985, Green et al. in prep., Haywood and Shackleton n.d., IEC Beak 1984, Kramer 1972, Nietfeld et al. 1984, Rolley and Keith 1979, Searing 1979, Sverre 1972, Thompson et al. 1980, Todd 1978, U.S. FWS 1980, Vriend and Barrett 1978).

Step 3

A 1:20,000 scale air photo mosaic was developed as the base map for the presentation of biophysical and, hence, habitat information (see map pocket on back cover of report). Land Systems were considered to be the sampling unit for habitat evaluations and quantification. The areal extent of these Land Systems and their nested Land Types was calculated for each reservoir site, using a computerized digitizer at the University of Calgary. For aquatic species, streamside habitat variables considered in the evaluation models (i.e., ground cover within the floodplain only, stream permanency, and stream sinuosity) were measured along 1 km segments or reaches of stream to permit variability along the stream length to be adequately detected.

A shortcoming of such a biophysical evaluation of habitat capability is the potential for areas with virtually no cover value to be assigned a relatively high overall HSI value, merely because of high food potential, or vice versa. This is particularly true in the ungulate models (particularly deer and elk), where expansive grasslands or pasture offer abundant food, but are of no value to these animals because of a complete lack of accessible cover. To prevent such areas from receiving an inflated and unrealistic HSI value solely because of food potential, we have developed certain modifying conditions in the ungulate model. In brief, those Land Systems lacking or more than 1 km from suitable cover (i.e. either a shrubland or forest block exceeding 2 ha in area) will be assigned a zero HSI value. We have not implemented similar modifications in the hare or pheasant models because of the ability of these species to use tall herbaceous vegetation as cover, in addition to localized pockets of shrubs or forest which may not have appeared on the Land System map.

4.3.4 Assessment of Habitat Availability

The quantification of overall habitat availability within a given area is frequently complicated when habitat quality is highly variable. For example, combining "good, fair and poor" habitat to evaluate total available habitat and to permit habitat comparisions between different sites is a difficult concept. To overcome such difficulties, the U.S. Fish and Wildlife Service (1980) has, as part of its Habitat Evaluation Procedures (HEP) program, developed a measure of habitat availability referred to as the Habitat Unit (HU). This unitless, standardized measure reflects both the quality and quantity of wildlife habitat within a given unit of land and, in formula, can be described as:

HU = HSI X A

where HU = the number of habitat units within a given land unit.

HSI = the habitat suitability index calculated for that given land unit for a given wildlife species

A = areal extent of that land unit

For the purposes of this study, Habitat Suitability Indices (HSI's) and areas were determined for each of the Land Systems (or reaches of stream) delineated for the four reservoir sites. Total Habitat Units available for each species were then calculated (as above) for each reservoir site to permit between site comparisons of habitat availability to be made. These values also permit the potential habitat loss or creation from a variety of project scenarios to be readily evaluated in future, once detailed engineering design becomes available.

4.4 RESULTS

4.4.1 Existing Wildlife Abundance and Distribution Data

4.4.1.1 Site 1: Willow Creek. Much of this site, including all of the valley of Willow Creek and adjacent uplands, is considered a key area for mule deer and white-tailed deer (AFWD Key Area Map: Claresholm) (see Figure 4-2). The site is mapped as a Class 3 wintering area (with slight limitations due to soil fertility) for deer and elk under the CLI system (Walsh and Walton 1972). It is bordered on the west by a larger Class 3 area for deer and elk, with limitations due to landform and fertility, and on the east by a very extensive Class 5 area for deer, with moderately severe limitations due to flatness and aridity. No data on ungulate densities are available.

Potential waterfowl and beaver habitat is provided by Willow Creek. Several small, largely intermittent waterbodies located within 1 km of the proposed reservoir shore also provide potential waterfowl habitat, but the area is mapped as CLI Class 6, with severe limitations to waterfowl production resulting from poor marshland development (Schick 1971). No specific information is available on actual waterfowl use of the area.

4.4.1.2 Site 2: Pine Coulee. The Pine Coulee site is not known to include any key ungulate habitat (AFWD Key Area Map: Claresholm). The valley of Pine Creek is all mapped by CLI as having Class 3 potential for deer and elk production, with moderate limitations due to landform and soil fertility (Walsh and Walton 1972). The site is bordered on the east by the same extensive Class 5 area as borders the Willow Creek site (Site 1), and on the west by a continuation of Class 3 habitat. The valley of Willow Creek to the west of the site, possibly including the area traversed by the proposed diversion system into Pine Creek, is considered to be a good area for white-tailed deer (J. Clark, pers. comm.), but survey data are not available.

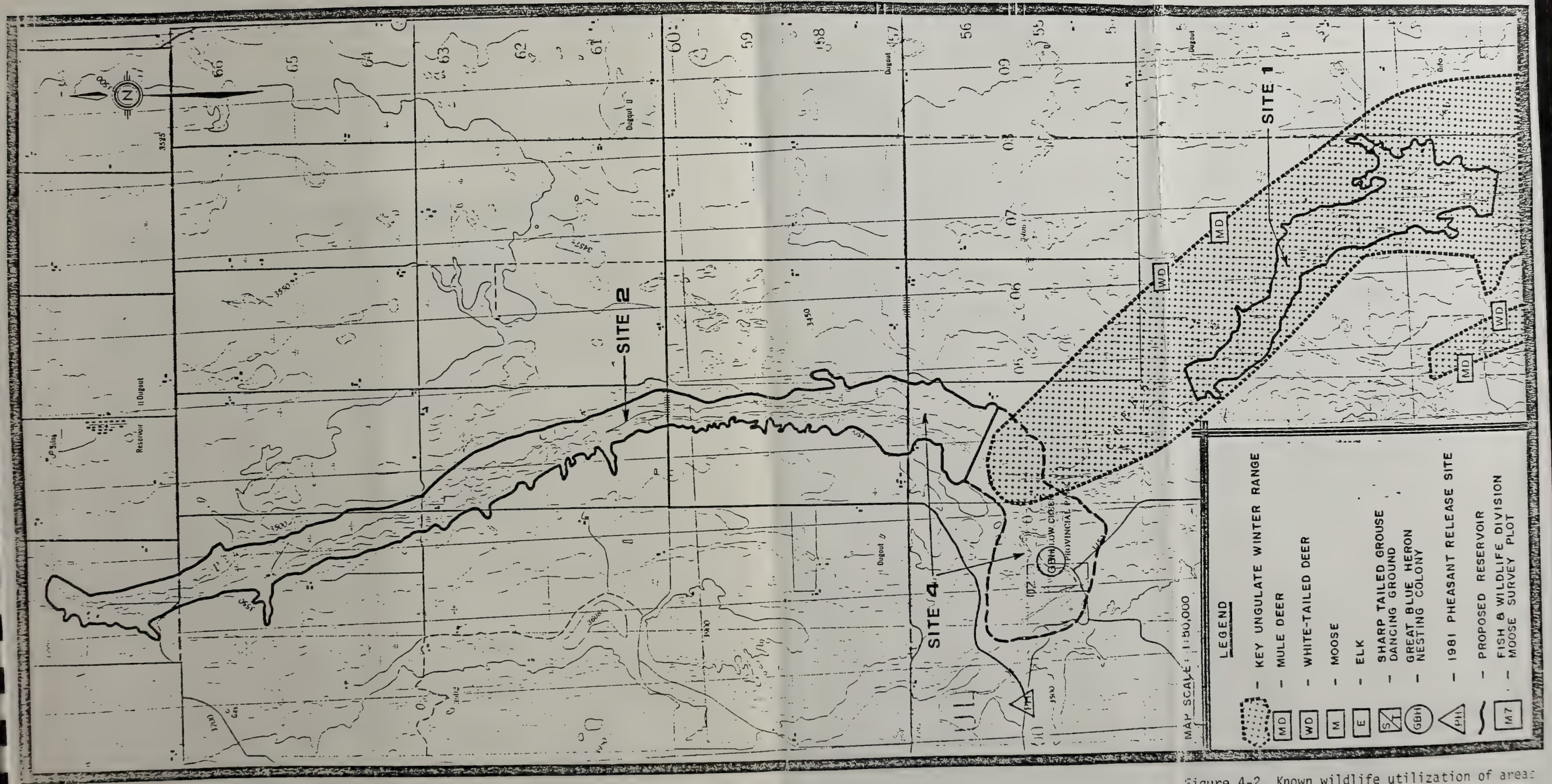

SITE 1
SITE 2
SITE 4
GBH
PH
MD
WD
Dugout
Reservoir
Gas
MAP SCALE: 1:50,000
LEGEND
KEY UNGULATE WINTER RANGE
MD – MULE DEER
WD – WHITE-TAILED DEER
M – MOOSE
E – ELK
SHARP TAILED GROUSE DANCING GROUND
GBH – GREAT BLUE HERON NESTING COLONY
PH – 1981 PHEASANT RELEASE SITE
– PROPOSED RESERVOIR
M7 – FISH & WILDLIFE DIVISION MOOSE SURVEY PLOT

Figure 4-2. Known wildlife utilization of areas within or near proposed reservoir Sites 1, 2 and 4.

Although a number of small wetlands are located within 1 km of the proposed reservoir shoreline, most of the area is CLI Class 6 capability waterfowl habitat, with severe limitations to waterfowl production resulting from adverse topography (Schick 1971). Small Class 4 areas (moderate limitations due to topography) are located along the eastern edge of the site, but no data are available on waterfowl occurrence in the area. The site appears to have no potential for beaver production.

4.4.1.3 Site 3: Kuntz Creek/Willow Creek. The Kuntz Creek site is bordered by key mule deer, elk and moose habitat on the south side of Willow Creek; these are the northern extensions of large habitats which have been delineated throughout the Porcupine Hills to the south (AFWD Key Area Maps: Claresholm and Langford Creek) (see Figure 4-3). However, the site itself does not fall within the borders of these key habitats. Based on CLI classification, the reservoir area is rated as as having only Class 3 capability for deer, elk and moose production, with slight limitations due to landform and fertility. The CLI program also identifies an extensive Class 3 wintering area for deer and elk to the south (Walsh and Walton 1972; Gunderson et al. 1970). Four aerial survey quadrats (each 1 mi2) that are surveyed biannually by AFWD occur within or immediately adjacent to the site (see Figure 4-3); in 1982 these quadrats contained a total of 9 moose, 10 mule deer and 2 coyotes (Gudmundson 1982), while in 1984 15 mule deer, 3 white-tailed deer, 25 elk and 1 coyote were sighted (Gudmundson 1984). Regional moose densities (including surrounding areas) were 3.5/mi2 in 1982 and 2.4/mi2 in 1984.

The site and an extensive surrounding area have very low capability for waterfowl production, and are rated as Class 6 and 7 by CLI (Schick 1971, Weaver 1971). The best potential waterfowl habitat is probably Willow Creek itself (where a female mallard and brood of 9 were observed on the 14 June field trip); the portion of Willow Creek flowing through this site also sustains some use by beavers (cuttings and old damsites were seen on the 14 June field trip).

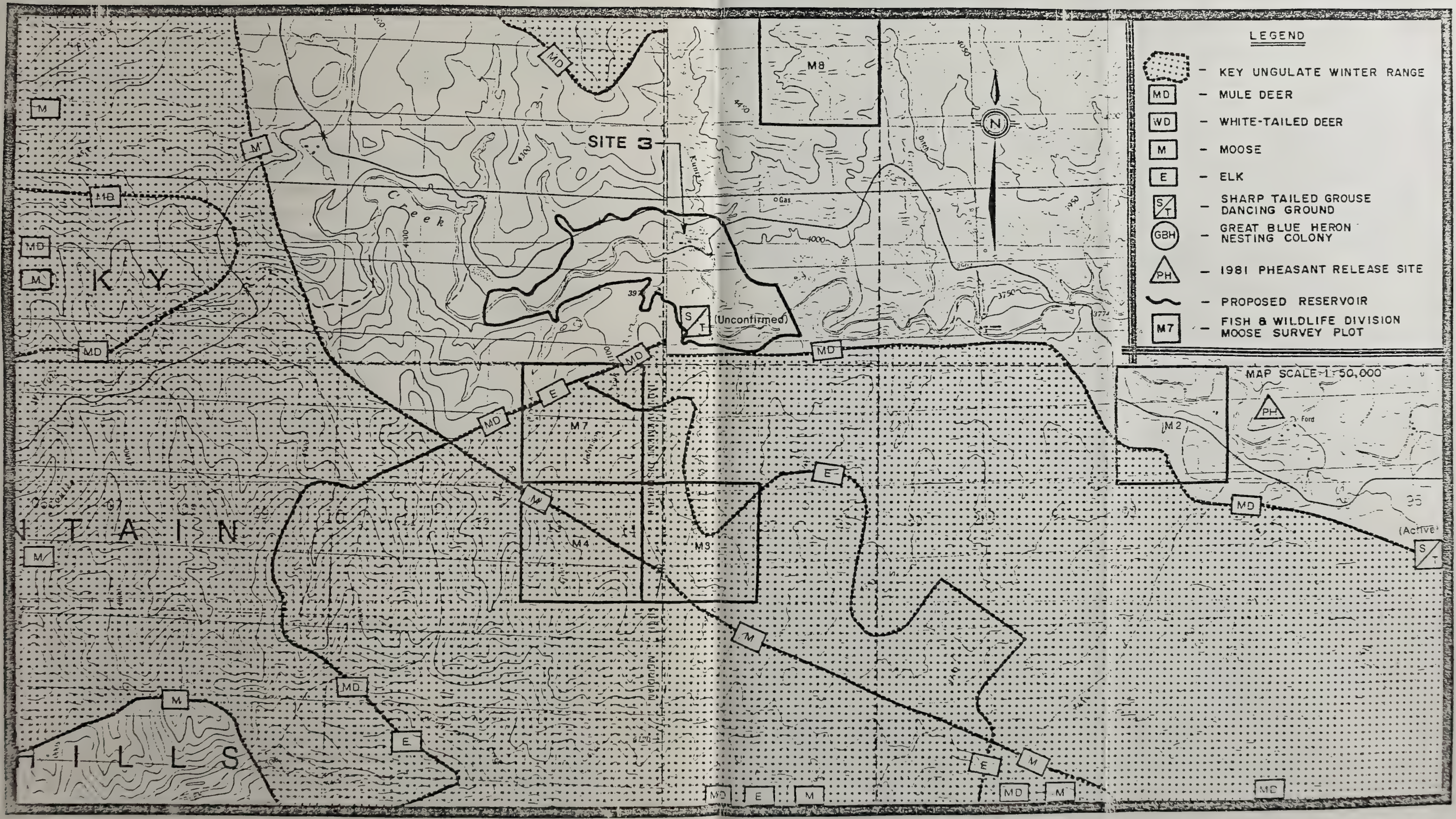

LEGEND
- KEY UNGULATE WINTER RANGE
MD - MULE DEER
WD - WHITE-TAILED DEER
M - MOOSE
E - ELK
S/T - SHARP TAILED GROUSE DANCING GROUND
GBH - GREAT BLUE HERON NESTING COLONY
PH - 1981 PHEASANT RELEASE SITE
- PROPOSED RESERVOIR
M7 - FISH & WILDLIFE DIVISION MOOSE SURVEY PLOT
MAP SCALE 1:50,000
SITE 3
N
(Unconfirmed)
(Active)
M8
M7
M4
M3
M2
Creek
Gas
Ford
K Y
T A I N
H I L L S

Figure 4-3. Known wildlife utilization of areas within or near proposed reservoir Site 3.

An unconfirmed sharp-tailed grouse dancing ground is located along Willow Creek, within the proposed reservoir basin (AFWD Key Area Map: Claresholm) (see Figure 4-3). No information is available on the occurrence of other upland gamebirds.

4.4.1.4. Site 4: Pine Coulee/Willow Creek. The limited use of Pine Coulee by wildlife has been previously discussed for Site 2. However, with the flooding of Willow Creek under the Site 4 scenario, this combined reservoir system takes on new wildlife significance. Key habitats for both mule deer and white-tailed deer extend a short distance (< 1 km) upstream of the proposed dam, on both Willow Creek and Pine Coulee (AFWD Key Area Maps: Claresholm). Based on CLI classification, that portion of Willow Creek to be impacted is rated as Class 3 wintering habitat for deer and elk.

Similar to Site 1, the relative permanence of Willow Creek at Site 4 does provide some potential habitat for beaver and waterfowl. The area has, however, received a Class 6 rating for waterfowl, largely because of the lack of marshland development in the area (Schick 1971).

A great blue heron colony is located at Willow Creek Provincial Park, approximately 1 km upstream of the proposed damsite (Brechtel 1981) (see Figure 4-2). This colony has been occupied since at least 1973 and in 1982 contained 16 nests, 6 of which were active (Clark 1982).

Young pheasants are transplanted annually in the valley of Willow Creek west of the site, and a breeding population reportedly has become established (J. Clark (Fish and Wildlife Branch, Lethbridge), pers. comm.).

4.4.2 Habitat Availability Comparisons

While several comparative statements about the presence or absence of wildlife or wildlife habitat can be made from information presented in the above sections for the four sites, no quantitative comparisons on wildlife potential are possible. However, the habitat evaluation models developed for this study permit an objective assessment of habitat quantity and quality to be made for each site. In Table 4-1, estimates of the total number of habitat units provided by each site for each evaluation species are provided. Each of these values have, in turn, been standardized to a per unit area basis (i.e. HU's per ha) to permit easy between-site comparisons of habitat quality to be made. In Part I of the table, both sets of values have been calculated for that area comprised of both the tentatively proposed reservoir, plus the 1 km-wide margin surrounding the area. This was done to provide a better regional assessment of habitat for the more mobile terrestrial species such as deer, elk, moose, hare and pheasant. Part II of the table provides values for both aquatic and terrestrial species, but only for the bottomland which would be affected by reservoir development. These values provide a clearer picture of habitat conditions within the stream-associated Land Systems for each site.

It should be noted that values for Table 4-1 were generated from the area and habitat suitability of the Land Systems comprising each site. Species-specific habitat suitability indices (HSI's) and areal estimates for the Land Systems are listed in Appendix 1 with the appropriate species write-up (see Tables 9-1 to 9-40 in Appendix 1).

In the sections below, brief biophysical descriptions are provided for each site, together with a discussion on the relative significance of the site from a wildlife perspective.

4.4.2.1 Site 1 - Willow Creek. A total of 1910 ha has been evaluated for this site, comprised of 333 ha of valley bottom, 220 ha of adjacent slopes and 1349 ha of bordering terraces (see Table 4-2). The bottomland has been described as a fluvial flood plain, characterized by level to undulating topography. In terms of vegetative cover, this lowland area is dominated by deciduous forest with seeded pasture and native grassland also being a common cover type.

Table 4-1 Habitat quantity and quality provided by the four potential sites.

SPECIES	Site 1 Total HU's	 HU's Per ha	Site 2 Total HU's	 HU's Per ha	Site 3 Total HU's	 HU's Per ha	Site 4 Total HU's	 HU's Per ha
I. Impoundment area and surrounding lands (within 1 km)								
Mule Deer	519.6	0.27	363.9	0.13	847.7	0.46	696.4	0.19
Elk	777.2	0.41	533.8	0.20	952.2	0.52	977.6	0.27
Moose	420.1	0.22	315.9	0.12	676.3	0.37	556.3	0.15
Snowshoe hare	264.3	0.14	439.1	0.16	779.9	0.43	618.7	0.17
Ring-necked pheasant	1105.7	0.58	1163.0	0.61	894.0	0.49	214.1	0.59
II. Impoundment area only								
Mule Deer	114.8	0.34	41.3	0.14	88.3	0.43	148.2	0.29
Elk	160.7	0.48	61.0	0.21	121.1	0.59	156.9	0.31
Moose	142.5	0.43	50.6	0.18	80.5	0.39	169.2	0.33
Snowshoe hare	140.2	0.42	105.6	0.27	97.7	0.47	220.7	0.44
Ring-necked pheasant	157.5	0.47	193.3	0.67	121.6	0.59	327.8	0.65
Beaver	231.5	0.69	102.2	0.35	146.5	0.70	206.0	0.41
Great Blue Heron	217.9	0.65	0.00	0.00	108.7	0.53	43.5	0.09
Mallard (Fall)	184.7	0.55	95.9	0.33	122.5	0.60	167.7	0.33
Mallard (Spring)	203.8	0.61	149.6	0.52	122.5	0.60	250.1	0.49

Table 4-2 Cover Type Breakdown of Site 1 - Willow Creek

COVER TYPE	VALLEY BOTTOM area(ha)	% area	SLOPES area(ha)	% area	UPLANDS area(ha)	% area
Deciduous Forest	92.4	27.7	1.9	0.8	0	0
Mixed Forest	0	0	0	0	0	0
Deciduous Parkland	9.6	2.9	0	0	0	0
Shrub Meadow	28.4	8.5	0	0	1.2	0.1
Shrubland	8.6	2.6	33.9	14.9	9.9	0.7
Native Grassland	60.1	18.0	149.3	65.5	98.0	7.3
Seeded pasture	77.2	23.2	0	0	380.8	28.2
Cultivated Crop	0	0	0	0	740.5	54.9
Seasonal Wetland	1.5	0.5	5.2	2.3	112.2	8.3
Permanent Wetland	0	0	0	0	0	0
Open Water	0	0	0	0	0	0
Bare Soil	55.3	16.6	37.6	16.5	6.9	0.5
TOTALS	333.1		227.9		1349.5	

TOTAL AREA OF SITE 1910.5

The slopes adjacent to the floodplain are comprised primarily of colluvial or fluvial material, with outcrops of bedrock occurring to a lesser degree. The more moderate, less eroded slopes support mainly native grassland, although some shrublands do occur on the more northernly aspects.

The flat terraces bordering the creek valley are mainly comprised of morainal material, with level to gently-undulating topography prevailing. Cultivated crops are the dominant vegetative cover, although seeded pasture and some native grassland are locally prevalent.

From a wildlife perspective, the mosaic of deciduous forest, shrublands and grasslands or pastures available on the bottomland and adjacent slopes of this site provides some food and cover for the majority of terrestrial species considered in the study. However, crops and grasslands dominate adjacent terraces. While providing a moderately reliable food supply for species which prefer herbaceous diets, the almost complete lack of cover in these areas greatly reduces their potential value for most animals. Consequently, Site 1 provides less available ungulate and hare habitat than Sites 3 and 4, and falls behind Sites 2 and 4 in the provision of pheasant habitat. It's overall habitat quality rating (i.e. HU's/ha) for the majority of terrestrial species is low to moderate.

Because of the relatively permanent nature of Willow Creek at Site 1 and the associated shrub and forest communities, the relative value of this site increases considerably when only bottomland is considered in the assessment. With the exception of mallard breeding habitat (i.e. spring habitat), Site 1 bottomland provides more habitat for aquatic species than all other sites and falls second only to Site 4 in the provision of ungulate and hare habitat. Its habitat quality rating remains moderate to high for all species.

4.4.2.2 Site 2 - Pine Coulee. A total of 2705 ha has been evaluated for this site, comprised of 288 ha of bottomland, 625 ha of adjacent slope and 1792 ha of bordering terraces (see Table 4-3). The bottomland can be described as a glacio-fluvial, meltwater channel. Its level to undulating topography is dominated by seeded pasture, native grassland and shrub meadows, with shrubland communities occurring to a lesser degree.

Slopes of the Coulee are moderate to steep, fluvial and colluvial deposits. They support mainly native grassland communities, with seeded pasture also being relatively prevalent. Shrub and forest dominated communities occur to a very limited degree.

Terraces bordering the Coulee are primarily level to gently undulating morainal deposits. Seeded pasture and cultivated crops dominate these areas, with native grassland also being relatively common.

From a habitat perspective, much of this site lacks a suitable cover component. Shrublands and shrub meadows do occur sporadically in the bottomland areas, providing some cover and non-herbaceous food sources, but forest cover is almost completely lacking. The dominance of cultivated crops, seeded pasture and native grasslands does ensure the presence of an extensive herbaceous food source for several species, but due to the lack of cover, results in limited overall capability for most animals. Consequently, this site ranks lowest in the provision of terrestrial wildlife habitat for all species except snowshoe hare (third) and pheasant (second). Its habitat quality rating is low for all species except pheasant.

Because of the intermittent nature of the stream and the lack of streamside food and cover in Pine Coulee, habitat values do not improve for this site even when bottomland alone is evaluated. It again ranks lowest in the provision of habitat for the majority of species, providing moderate habitat quantities and quality for pheasant and mallard (spring breeding habitat) only.

Table 4-3 Cover Type Breakdown of Site 2 - Pine Coulee

COVER TYPE	VALLEY BOTTOM area(ha)	VALLEY BOTTOM % area	SLOPES area(ha)	SLOPES % area	UPLANDS area(ha)	UPLANDS % area
Deciduous Forest	0	0	12.9	2.1	1.2	0.1
Mixed Forest	0	0	0	0	0	0
Deciduous Parkland	0	0	0	0	0	0
Shrub Meadow	117.3	40.7	46.7	7.5	11.5	0.6
Shrubland	11.2	3.9	46.7	7.5	4.2	0.2
Native Grassland	81.0	28.1	307.4	49.2	229.7	12.8
Seeded pasture	71.1	24.7	172.8	27.7	614.0	34.3
Cultivated Crop	0	0	31.1	5.0	842.5	47.0
Seasonal Wetland	0	0	0	0	44.3	2.5
Permanent Wetland	0	0	0	0	36.8	2.1
Open Water	0	0	0	0	0	0
Bare Soil	7.6	2.6	7.2	1.2	6.6	0.4
TOTALS	288.2		624.8		1791.9	

TOTAL AREA OF SITE 2704.9

4.4.2.3 Site 3 - Kuntz Creek/Willow Creek. A total of 1830 ha has been included for evaluation in this third site. Because of its narrow-valley configuration, it is comprised of only 205 ha of bottomland, with adjacent slopes and terraces contributing 717 and 908 ha, respectively (see Table 4-4). The bottomland is comprised of relatively level fluvial fans, terraces and floodplains, and supports a complex mosaic of cultivated crops, shrublands, deciduous forest and seeded pasture (in decreasing order of dominance).

Slopes bordering the bottomland are well vegetated, relatively steep, colluvial material. Native grassland is the dominant cover type, with deciduous forest, shrubland, seeded pasture, and shrub meadows also occurring to a considerable degree.

The terraces adjacent to the valley are predominantly comprised of level to moderately-sloped morainal deposits, although steep fluvial channels also intersect the area. Native grassland heavily dominates the vegetation in the area, with shrublands being the only other significant cover type.

From a wildlife perspective, this site provides a good mosaic of food and cover sources for all of the terrestrial species considered in the report. In spite of its small size, relative to the other sites, this site is ranked first in the provision of terrestrial wildlife habitat for all species except elk (second and almost equal to Site 4 values) and pheasant (fourth). Its low value for pheasant reflects the greater occurrence of forests and shrublands relative to other sites and the associated reduction in preferred pheasant feeding habitats (i.e. grasslands and croplands). The habitat quality ratings for Site 3 are higher than those of the remaining sites for all terrestrial species except pheasant.

Bottomland at Site 3 also represents moderate to high quality habitat for all of the evaluation species. Although seasonal or permanent wetlands are limited in area (< 4 ha), the permanence and slow-flowing nature of Willow Creek itself, coupled with a variety of

Table 4-4 Cover Type Breakdown of Site 3 - Kuntz Creek/Willow Creek

COVER TYPE	VALLEY BOTTOM		SLOPES		UPLANDS	
	area(ha)	% area	area(ha)	% area	area(ha)	% area
Deciduous Forest	33.5	16.3	132.8	18.5	25.9	2.9
Mixed Forest	0	0	45.0	6.3	5.0	0.6
Deciduous Parkland	0	0	16.7	2.3	1.2	0.1
Shrub Meadow	1.4	0.7	61.1	8.5	58.3	6.4
Shrubland	52.5	25.6	99.3	13.8	190.1	20.9
Native Grassland	0	0	252.1	35.1	594.3	65.5
Seeded pasture	33.5	16.3	82.6	11.5	17.1	1.9
Cultivated Crop	70.3	34.3	13.5	1.9	11.1	1.2
Seasonal Wetland	0	0	0.5	0.1	3.6	0.4
Permanent Wetland	0	0	0	0	1.1	0.1
Open Water	0	0	0	0	0	0
Bare Soil	13.1	6.7	13.9	1.9	0	0
TOTALS	204.9		717.5		907.7	

TOTAL AREA OF SITE 1830.1

shoreline food and cover sources, make this area highly suited to aquatic species as well as terrestrial. However, because of its restricted areal extent, bottomland at this site ranks third (behind Sites 1 and 4) in the provision of habitat units for ungulates, beaver, and mallard (summer-fall habitat), second for heron and fourth for hare and pheasant.

4.4.2.4 Site 4 - Pine Coulee/Willow Creek. As previously discussed, Site 4 is a multi-drainage reservoir which floods both Pine Coulee and Willow Creek. It will inundate that area discussed for Site 2 in addition to the remainder of the Pine Coulee system downstream to Willow Creek and several km of Willow Creek proper. A total of 3586 ha have been evaluated for this site, comprised of 464 ha of valley bottom, 916 ha of slopes and 2206 ha of adjacent terraces (Table 4-5). It should be noted that only 881 ha (25%) of the 3586 ha constitutes new area not previously evaluated for Site 2. This new area is comprised of 176 ha of valley bottom, 291 ha of adjacent slopes and 414 ha of elevated terraces. The valley bottom outside of Site 2 has been described as an active flood plain comprised of fluvial deposits and characterized by level to undulating topography. It is dominated by deciduous forest, shrubland and seeded pasture, with shrub meadows and cultivated crops occurring to a lesser degree. Slopes bordering Willow Creek at this location are moderately steep, yet well vegetated colluvium. Native grassland and seeded pasture dominate the vegetative cover, with shrubland, shrub meadow and bare soil also being present. Similar to Site 1, the terraces bordering Willow Creek at Site 4 are gently undulating morainal deposits. Seeded pasture and native grassland comprise more than 95% of the vegetative cover.

From a wildlife perspective, the presence of deciduous forest, shrublands and shrub meadows adjacent to seeded and native pastures in the southern portion of the site provides an attractive,albeit localized, mosaic of food and cover sources for a variety of terrestrial species. When coupled with the expansive, grassland and cropland-dominated areas of Pine Coulee to the north,

Table 4-5 Cover Type Breakdown of Site 4 - Pine Coulee/Willow Creek

COVER TYPE	VALLEY BOTTOM area(ha)	VALLEY BOTTOM % area	SLOPES area(ha)	SLOPES % area	UPLANDS area(ha)	UPLANDS % area
Deciduous Forest	42.5	9.2	13.6	1.5	1.2	0.1
Mixed Forest	0	0	0	0	0	0
Deciduous Parkland	8.9	1.9	0	0	0	0
Shrub Meadow	146.6	31.6	62.1	6.8	11.5	0.5
Shrubland	50.4	10.9	54.5	6	6.4	0.3
Native Grassland	81.0	17.5	495.0	54.1	404.7	18.3
Seeded pasture	109.2	23.5	234.4	25.6	847.8	38.4
Cultivated Crop	13.3	2.9	31.1	3.4	842.5	38.2
Seasonal Wetland	0	0	0	0	45.4	2.1
Permanent Wetland	0	0	0	0	36.8	1.7
Open Water	0	0	0	0	0	0
Bare Soil	12.2	2.6	24.9	2.7	10.2	0.5
TOTALS	464.1	12.9	915.6	25.5	2206.5	61.5

TOTAL AREA OF SITE 3586.2

this site ranks second in the provision of terrestrial habitat for mule deer, moose and snowshoe hare, and first for pheasant and elk.

However, it should be recognized that more than 40% of the habitat units provided for mule deer, elk and moose by this site are contributed by that localized portion of Willow Creek involved in the flooding scenario. Because Pine Coulee offers little high quality habitat, the overall quality rating for this site on a per ha basis is low for all species but pheasant.

When bottomland only is considered in the assessment of habitat, Site 4 ranks highest in the provision of habitat units for mule deer, moose, hare, pheasant, and mallard (spring only), second for elk, beaver, and mallard (summer/fall) and third for heron. However, it must again be recognized that the majority of this available habitat is concentrated along Willow Creek. Consequently, habitat quality ratings for this site on a per ha basis are relatively low for all species except pheasant.

4.5 REGIONAL SIGNIFICANCE OF IMPACTS FROM FLOODING

4.5.1 Site 1 - Willow Creek

Although supporting only moderate habitat quality for the majority of evaluation species considered in this study, Site 1 constitutes an area of considerable regional significance to wildlife. The forest and shrubland communities supported along Willow Creek provide the only significant cover for animals exploiting the surrounding grassland and cropland areas, in addition to creating an adequately protected movement corridor for animals migrating between agricultural lands and the adjacent Porcupine Hills (e.g. mule deer, elk). Because of these factors, the site falls within an area considered to be key mule deer and white-tailed deer habitat by the Alberta Fish and Wildlife Division. Consequently, the site has been rated second in terms of vulnerability to flooding-rating impacts, a rating comparable to that assigned to Site 4.

4.5.2 Site 2 - Pine Coulee

With the exception of providing considerable hare, pheasant and, to a lesser degree, mallard habitat, Site 2 offers little from a wildlife perspective. Its lack of streamside cover and permanent water greater reduces its potential for the remaining evaluation species. Consequently, it has been rated last in terms of vulnerability to flooding-related impacts.

4.5.3 Site 3 - Kuntz Creek/Willow Creek

In spite of its relatively small size, this site encompasses considerable amounts of high quality habitat for all evaluation species. It is situated within the Porcupine Hills, a biophysical region supporting extensive tracts of aspen parkland and shrub communities and considerable terrestrial wildlife capability. Consequently, it could potentially provide low-elevation habitat features (e.g. water source, reduced snow accumulations) for a large number of animals. Its bottomland also provides a high quality habitat source for aquatic species. Because the development of the reservoir and associated reservoir recreational activities at this site would adversely affect relatively large numbers of animals and high quality habitat, this site has been ranked as most vulnerable to project impacts.

4.5.4 Site 4 - Pine Coulee/Willow Creek

Although Pine Coulee, as previously discussed, offers little wildlife capability, that portion of Willow Creek affected by this flooding scenario has much greater significance. Similar to Site 1, the forest and shrublands along Willow Creek offer both cover and a protected movement corridor for a variety of species, although only a portion of this area is classified as key mule deer and white-tailed deer habitat by the Alberta Fish and Wildlife Division. Site 4 offers th added advantage to wildlife of having a "wildlife protection area" status in the vicinity of Willow Creek Provincial Park. It also supports the only known active heron colony in this portion of the Willow Creek basin and a possibly viable pheasant population.

Consequently, this site has been considered second most vulnerable to potential project impacts, and of comparable vulnerability to that of Site 1.

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5.0 FISHERIES

5.1 COMPONENT REQUIREMENTS

1. Provide, at an overview level, an understanding of species composition, distribution, and relative abundance in Willow Creek and Pine Creek. If possible from existing data, identify any important fish migrations.
2. Assess the fish habitat and capability of the creeks, and their limitation to support fisheries under present flow conditions.
3. Assess the significance of the location of each site in terms of the habitat lost, potential effect of flow regulation on the fishery downstream of the reservoir, and the fishery potential of the reservoir.
4. Provide an assessment of the present and future value and utilization of the fisheries resources of Willow Creek.

5.2 APPROACH AND RATIONALE

Similar to the wildlife component, both population/abundance data and habitat data were utilized to assess the fisheries resource in the three proposed reservoir sites. Actual census, harvest and species distribution data permitted some assessment of the composition, relative abundance and current utilization of fish within the Willow and Pine Creek drainages. However, the information base was not sufficiently detailed to permit a very quantitative assessment of current conditions and potential impacts to be made. Consequently, this information was augmented by an assessment of current physical conditions and those which would likely develop within and downstream of the proposed reservoirs, given the preliminary engineering design for the sites (Klohn Leonoff 1984). Using these two sources of information, the basic approach of the fisheries component was:

1. To characterize stream habitats in each of the potential reservoir sites;
2. To identify any known critical areas (spawning, rearing, and overwintering areas as well as migration routes).
3. To summarize those aspects of construction, filling and operation of the reservoirs which might affect fish habitat and fish populations in the drainage.
4. To assess the potential impacts, positive or negative, of reservoir development on fish habitat and fish populations whether in stream reaches upstream of reservoirs, within the reservoirs themselves or in stream reaches downstream.
5. To compare the four potential reservoir sites in terms of current potential and in terms of the kinds of fisheries-related impacts which may occur, their magnitude, duration and geographic extent, as well the potential for mitigation.

5.3 METHODS

A compilation of relevant existing information on fish distribution and habitats in the area involved a library literature search, a review of all published and unpublished literature from relevant Fish and Wildlife Division files in Lethbridge, and interviews with regional fisheries biologists. To permit some level of impact assessment to be made, three additional steps were taken. These included:

1. an examination of current engineering design considerations for the reservoirs, including reservoir area, depth, and quantity and seasonality of discharge;

2. discussions with water quality personnel on the current water quality conditions at the sites and the potential dam-related changes to physical and chemical conditions which may affect fish populations; and

3. a review of relevant literature concerning fish populations and reservoir development.

5.4 RESULTS

5.4.1 Stream Characteristics and Habitat

English (1984) presents information on stream habitats and biological resources in Willow Creek downstream of Chain Lakes Reservoir. He describes this section of Willow Creek as comprised of three separate reaches (Figure 5-1):

REACH A	The upper reach, which extends from the Chain Lakes Reservoir to a point approximately 54 km downstream.
REACH B	The middle reach, which extends approximately 50 km from below Willow Creek Provincial Park to a point northwest of Granum.
REACH C	The lower reach, which includes the lower 47 km of the stream to its mouth.

Reach A of Willow Creek drains the foothills area in and around the Porcupine Hills. In this reach, the stream has a mean gradient of 4.7 m/km, and a mean width of 17.6 m (Table 5-1). The channel has a variety of substrate types, a high percentage of riffle area, and good pools which often have adequate cover in the form of overhanging banks or vegetation. Since channel depth often exceeds 1 m, even under low flow conditions, many pools in this reach have the potential to support overwintering sports fish.

Figure: 5-1 Reaches A, B and C of the Willow Creek Drainage as defined by English (1984)

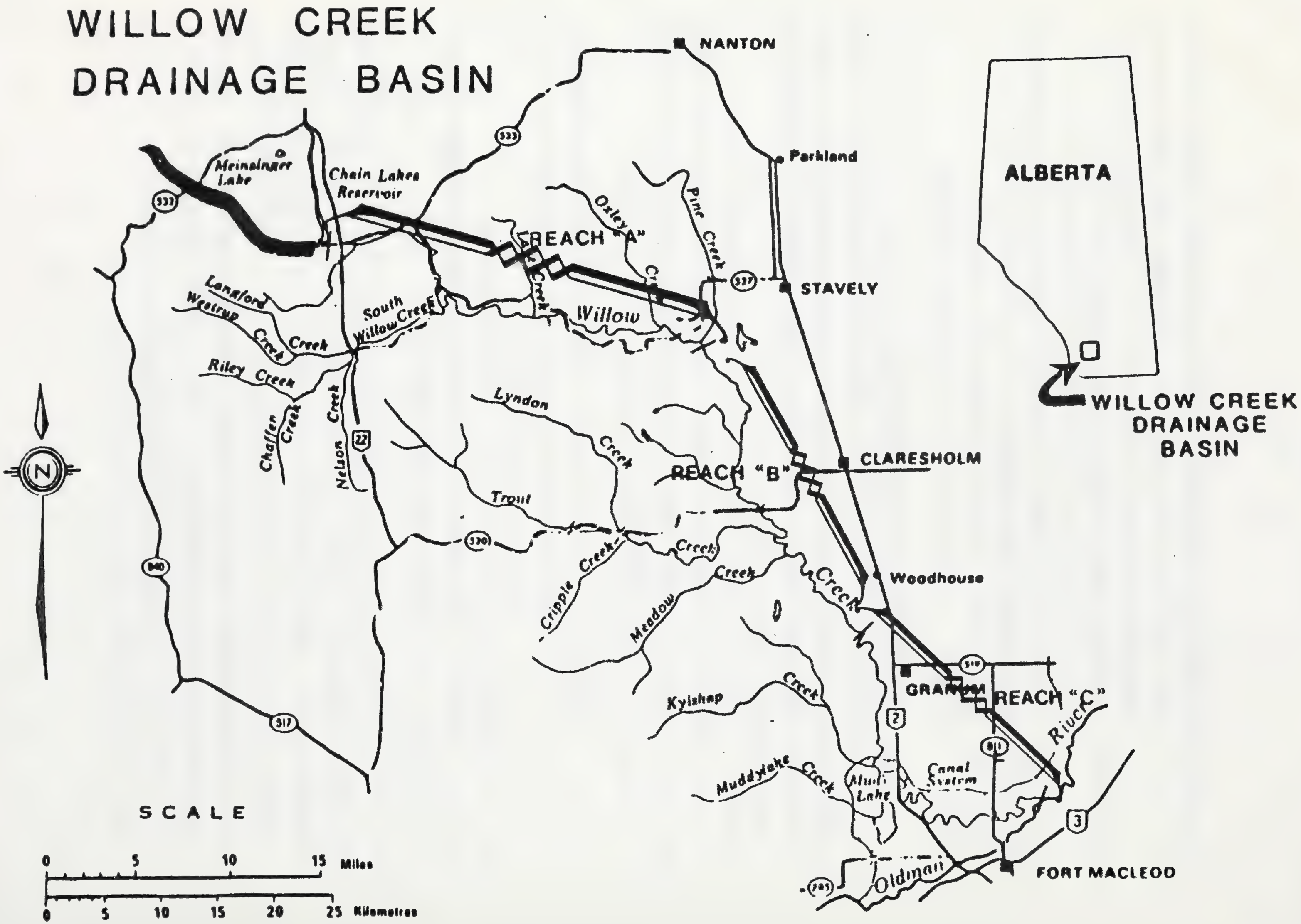

Table 5-1 Stream Channel Characteristics of three reaches of Willow Creek, August 1981 (Data from English 1984)

REACH	A	B	C
Number of transects	22	18	18
Approximate lenth(km)	54	50	47
Average width(m)	17.6	19.1	24.8
Average depth(m)	27.5	36.3	34.8
Surface Area(ha)	88	95.5	124
Riffle Area	62%	16%	31%
Pool Area	32%	84%	69%
Pool Quality			
Class 1	54%	74%	36%
Class 2	20%	18%	47%
Class 3	5%	0%	12%
Class 4	0%	0%	0%
Class 5	21%	8%	5%
Number of Over/wintering pools	Frequent	Frequent	Frequent
Substrate			
Boulders	7%	1%	4%
Rubble	41%	13%	48%
Gravel	38%	36%	15%
Sandsilt	12%	50%	34%
Other	3%	0%	0%
Number of Fish Barriers	0	0	0
Bank Vegetation:			
Forest	1%	0%	0%
Brush	1%	9%	22%
Open	56%	91%	78%
Unstable Banks	49%	77%	56%
Average Gradient(m/km)	4.7	1.2	1.3
Approximate Dischange(m/sec)	3.6	3.8	3.0
Average Velocity(m/sec)	0.76	0.62	0.63
Dates Surveyed	August 11	August 11-12	August 12-13

Reach B of Willow Creek is characterized by long, slow, open pools. The mean gradient of this reach is 1.2 m/km. The channel substrate is primarily sand and silt with some gravel and occasional rubble. The shallow water in this reach (water depths seldom exceed 1 m) reduces its potential to support overwintering sports fish.

Reach C of Willow Creek has a mean channel width of 24.8 m (Table 5-1). The stream channel is almost entirely devoid of cover provided by overhanging banks or vegetation. There is more rubble substrate in Reach C than in Reach B, and a slightly higher percentage of riffle area. As in Reach B, water depths rarely exceed 1 m, and the water appears to be somewhat shallower than it is in Reach B.

Of the four reservoir sites proposed for Willow Creek, Site 1 would be wholly within Reach B, near its upper end; Site 2 would be offstream in Pine Coulee; Site 3 would be wholly within Reach A, near its upper end and Site 4 would be in the bottom end of Reach A, as well as offstream in Pine Coulee. The reservoir at Site 2 would require a diversion in Willow Creek, just upstream of Willow Creek Provincial Park, involving a diversion channel which would enter the reservoir at its downstream end, and an outlet channel to Willow Creek just downstream of the park. Thus, water for Site 2 would originate in the lowermost end of Reach A and re-enter Willow Creek near the boundary between Reach A and Reach B.

5.4.2 Benthic Macroinvertebrates

Data from English (1984), describing benthic macroinvertebrate communities within the three stream reaches, are summarized in Table 5-2. The overall mean number of organisms per transect was similar for the three reaches, ranging from 354 to 431 organisms. There was, however, a proportionately much greater range in overall mean weight (i.e., biomass) per transect. The highest biomass was in Reach B (5.41 g overall, largely as the result of a very high spring value of 12.84 g) and lowest in Reach A (1.21 g/transect).

Table 5-2 Summary of data describing benthic macroinvertebrate samples collected by dipnet in spring (April), summer (July), and autumn (October), 1981. Data from English (1984).

REACH	A				B				C			
SEASON	Spring	Summer	Fall	Total	Spring	Summer	Fall	Total	Spring	Summer	Fall	Total
Number of Transects (n)	3.0	3.0	3.0	9.0	3.0	3.0	3.0	9.0	6.0	6.0	6.0	18.0
Mean Organisms/ Transect (n)	680.0	202.0	321.0	401.0	474.0	134.0	453.0	354.0	567.0	142.0	585.0	431.0
Mean Weight/ Transect (g)	1.1	.4	2.1	1.2	12.8	2.7	.7	5.4	3.1	.2	1.4	1.6
Mean % Composition(%)												
Ephemeroptera	68.2	86.4	37.1	63.9	20.2	68.1	32.7	40.3	27.6	36.6	26.9	30.4
Plecoptera	10.9	.9	1.6	4.5	2.4	3.4	11.3	5.7	6.8	1.5	3.5	3.9
Trichoptera	9.3	3.6	34.8	15.9	29.2	16.4	29.9	25.2	13.5	11.5	44.0	23.0
Diptera	11.3	6.9	24.0	14.2	42.3	8.9	24.1	25.1	46.5	46.2	23.9	38.9
Miscellaneous	.1	2.3	2.2	1.5	5.8	2.9	2.0	3.7	5.6	4.2	1.7	3.8

There was a distinct trend in the relative abundance of major groups, with the highest combined representation of Ephemeroptera, Plecoptera, and Trichoptera in the uppermost Reach A (84.3% overall), and the lowest in the lowermost Reach C (57.3% overall). These organisms are generally considered to be the most important food organisms for stream dwelling fish. There was a complementary increase in the representation of Diptera, presumably mostly Chironomidae, from 14.2% overall in Reach A to 38.9% overall in Reach C.

5.4.3 Fish

Table 5-3 summarizes data describing the distribution of fish species in Chain Lakes Reservoir and in the three reaches of Willow Creek downstream of Chain Lakes in 1981. In total, 17 species of fish were taken, though no more than 12 occurred in any individual reach. Six species are considered to be sports species: mountain whitefish, rainbow, brown, brook, and bull trout, and northern pike. The latter is a cool water species, the other five are cold water species.

English (1984) indicates that the trout species are largely confined to the 50 km reach (Reach A) from Chain Lakes to Willow Lake Provincial Park (Table 5-4). Downstream of the park, high summer water temperatures and low winter flows appear to limit the distribution of cold water species. (There are, however, some reports of angler catches of brown trout near the mouth of the creek, possibly fish which have moved upstream from the Oldman River to feed during the summer.) The rainbow trout fishery in Reach A immediately below Chain Lakes Reservoir may be supported, in part, by trout from the reservoir, which is stocked annually.

Downstream of the park, in Reaches B and C, the fish community is a cool water one comprised of northern pike, burbot, four species of suckers and several forage species, English (1984) collected young-of-the-year mountain whitefish in the lower reaches of Willow Creek, but no adults were found.

Table 5-3 Fish species reported for Chain Lakes (MacNeill 1978) and for three reaches of Willow Creek downstream of Chain Lakes (English 1984).

COMMON NAME	SCIENTIFIC NAME	LAKES	A	B	C
Mountain Whitefish	Prosopium williamsoni	X	X	X	X
Cutthroat Trout	Salmo clarki	X			
Rainbow Trout	Salmo gairdneri	X	X	X	X
Brown Trout	Salmo trutta		X		
Brook Trout	Salvelinus fontinalis	X	X		
Bull Trout	Salvelinus confluentis	X	X		
Northern Pike	Esox lucius			X	X
Lake chub	Couesius plumbeus	X	X	X	X
Emerald Shiner	Notropis atherinoides	X			X
Spottail Shiner	Notropis hudsonius			X	X
Fathead Minnow	Pimephales promelas	X			
Longnose Dace	Rhicichthys cataractae	X	X	X	X
Longnose Sucker	Catostomus catostomus	X	X	X	
White Sucker	Catostomus commersoni	X	X	X	X
Mountain Sucker	Catostomus platyrhynchus	X	X	X	X
Northern Redhorse Sucker	Moxostoma macrolepidotum			X	X
Burbot	Lota lota			X	X
Brook stickleback	Culea inconstans		X		
Trout-perch	Percopsis omiscomaycus		X	X	X
Spoonhead sculpin	Cottus ricei	X			
Total Species (n)		13	12	12	12

Table 5-4 Percent composition of gamefish catch, by reach, in Willow Creek, 1981. P indicates present but not captured. Data from English (1984).

	REACH			
	A	B	C	Overall
Total catch	73	4	25	102
% Composition by species				
Mountain Whitefish	32	25	44	34
Rainbow Trout	64	50	8	50
Brown Trout	P			P
Brook Trout	3			2
Bull Trout	1			1
Northern Pike		25	48	13

Little is known about the movements of fish in Willow Creek. W.G. English, Regional Fisheries Technician, Fish and Wildlife Division, Lethbridge (personal communication) feels that the trout species in Reach A are probably relatively stationary, undertaking only short seasonal migrations, but he notes (English 1984) that the distribution of young-of-the-year whitefish suggests either that mountain whitefish migrate into Willow Creek from the Oldman River to spawn, or that young-of-the-year move down from the upper section of Reach A where there is a population of this species. There seems to be no information available concerning the movements of cool water sports fish or coarse species in the drainage downstream of Chain Lakes Reservoir.

5.5 POTENTIAL IMPACTS OF RESERVOIR DEVELOPMENT - GENERAL CONSIDERATIONS

This section is a general review of the kinds of impacts on aquatic resources which occur as the result of reservoir development on streams.

5.5.1 Upstream of Development

Upstream of impoundments, it is possible for changes in fish populations to occur as a result of development. These changes have mainly to do with alterations in the distribution and relative abundance of fish species, which come about because of the presence downstream of the impoundment and dam, and not because of any physical change in the upstream portion of the drainage.

Hynes (1970) discusses the problem of upstream effects and states that the biological effects result from blockage of the upstream migration of fish which formerly utilized the area, and consequent reductions in, or the elimination of, migratory fish populations. A further upstream effect can result when large populations of certain species develop in impoundments, then migrate upstream into streams where they were previously absent or rare (Ruhr, 1957). This can come about in two ways:

1. The species becomes extremely abundant in the reservoir and expands into formerly marginal habitats; or
2. The flooding of the reservoir eliminates barriers to fish passage (e.g. beaver dams, rapids, falls) which may have existed prior to impoundment.

Expansion of the distribution of fish species may be advantageous if the species are desirable ones (e.g. trout), but disadvantageous if coarse (e.g. white and longnose suckers) or less valuable sports species (e.g. pike) become abundant in areas that now serve as suitable habitat for trout and whitefish.

Walton (1980) studied the suckers of Upper Willow Creek and the Chain Lakes Reservoir from April 1975 to January 1977. He found that the rapid increase in sucker populations in the reservoir had resulted in a similar expansion in the numbers of suckers spawning in Upper Willow Creek upstream of the reservoir. During his period of study, approximately 11,400 white and 795 longnose suckers utilized the lower 11 km of the stream during the peak of spawning in May.

5.5.2 Within Impoundments

5.5.2.1 Primary Production. Reservoirs inundate rich bottom lands from which mineral nutrients and organic materials are leached immediately after closure (Sylvester and Seabloom 1966). The relatively high initial levels of plant nutrients encourage the development of dense algal populations with a high primary productivity. As the rate of leaching declines, algal populations and primary productivity fall. As a result, reservoirs tend to be most productive early, and productivity tends to decline with age. The decomposition of organic materials, both those incorporated in the lake bottom and those produced by algae can lead to severe oxygen depressions in the bottom waters of newly created reservoirs, with possible adverse effects on fish populations.

5.5.2.2 Aquatic Invertebrates. Nilsson (1961,1964), Runnstrom (1955), Kimsey (1957), and Paterson and Fernando (1970) have commented on the colonization of new reservoirs by invertebrate fauna. The following appears to be a typical pattern:

1. During the very early stages of initial flooding, terrestrial insects and earthworms constitute a large proportion of the total invertebrate biomass (by weight);

2. Zooplankton populations, particularly Cladocera, increase rapidly, then decline to lower but still substantial levels;

3. During the initial flooding, benthic macroinvertebrates populations increase substantially as many groups of stream-dwelling invertebrates (oligochaetes, nematodes, oribatoid mites, and chironimids) invade the new habitat;

4. Within a few months, invertebrates of both terrestrial and stream origin are largely replaced by a lake-dwelling fauna which invades the reservoir during the summer temperature rise.

5. During the winter, many species are eliminated by freezing and ice scour as reservoir levels decline. The group that suffer most are the larger crustaceans (e.g. amphipods such as *Gammarus*, an important fish food), the larvae and nymphs of large insects, and the molluscs. Among the Chironomidae, the tribe Chironimini disappear in favour of the Tanytarsini.

6. With respect to species composition, it is likely that the invertebrate fauna is essentially complete by the end of the first summer of the reservoir's existence, though it may be several years before the fauna is stabilized in terms of relative abundance.

The overall pattern is one of high invertebrate densities early in the life of the reservoir and lower, more stable levels as the reservoir ages. The most striking difference between reservoirs and natural lakes is in the depth distribution and overall densities of their benthic invertebrate populations. Natural lakes have their maximum densities in shallow water; whereas, in regulated lakes and reservoirs the greatest densities occur at depths below the limit of maximum drawdown. As a result of the reduction in the benthic fauna which occurs because of the unstable environment between the full supply level and the limit of drawdown, regulated lakes and reservoirs are generally less productive of fish food organisms than natural lakes which are otherwise comparable.

In general, the greater the proportion of total area exposed during drawdown, the greater the reduction in benthic invertebrate production. In irrigation reservoirs, drawdowns during normal operations can expose large areas of bottom. Aside from the effects on invertebrate populations, this sometimes results in severe soil erosion from the action of wind as the muds dry.

5.5.2.3 Fish. Impoundment results in profound changes in the environment within the flooded area with correspondingly major effects on fish populations. Kimsey (1957) describes a situation in impounded waters in California and the lower Colorado River which appears to be typical of fish populations in reservoirs:

> Over a period of years, following construction, the reservoirs experience a typical pattern of high initial fishing success, a sharp decrease, and then a gradual rise to a fishery somewhere near half the magnitude of the initial phase. The decrease is believed to be the result of the high initial fertility, characteristic of newly flooded lands, being leached out by repeated fluctuation. The readjustment of the fishery to a lower level is the result of its adjustment to the basic fertility of the basin.

There may also be changes in the relative abundance of various species, as those species well-adapted to the effects of impoundment and regulation increase in abundance, while ill-adapted species decline. Experience with planting rainbow trout in other reservoirs in southern Alberta has been similar: a period of rapid growth and high fishing success, followed by the collapse of the population and its disappearance as competing species, better suited to conditions in the reservoir,become established and increase.

Miller and Paetz (1959), for example, report that the introduction of rainbow trout in Sherburne Reservoir in 1954 and 1955

> ...proved very successful. Trout of 12 to 16 oz. [340 to 450 g] were caught by September of 1954 and, during the next two summers, the lake provided an excellent trout fishery. Deterioration of angling success followed in 1957, although some large trout were known to be present.

A restocking in 1958 failed, and rainbow trout are not now found in the reservoir. It would appear that, unless other species can be denied entry, the planting of rainbow trout, particularly in prairie reservoirs, can be viewed as only a short-term measure designed to provide a high-intensity fishery for a period of only a few years.

5.5.3 Downstream of Impoundments

5.5.3.1 Primary Productivity. The increased nutrient loads and higher productivity which results from the leaching of soils and organic materials during the initial flooding of the reservoirs should result in a corresponding increase in productivity downstream. This effect should be temporary as it is in the reservoir.

5.5.3.2 Aquatic Invertebrates. The effects of impoundment on aquatic invertebrate populations downstream vary considerably depending on the operating characteristics of the reservoir and the resultant flow regime. On the one hand, increased stability, reduced turbidities, and increased loadings of organic materials and nutrients improve habitat and encourage the development of invertebrate populations. As a result of such factors, some authors have found evidence of increased invertebrate populations downstream of reservoirs (e.g. Spence and Hynes 1971) coupled with:

1. A reduction in the total number of species;
2. An increase in the numbers of individuals of some species; and
3. The replacement of some species by closely related ones.

On the other hand, severely reduced flows, such as sometimes occur downstream of mainstream irrigation reservoirs, and changes in the natural temperature regime can be very damaging.

5.5.3.3 Fish. Some of the major downstream effects of impoundment on fish are related to changes in natural discharge and temperature regimes, changes in water quality, and blockage of upstream migrations. One of the characteristics of impoundments operated to provide irrigation water is that flows are often radically reduced, particularly during summer, the period of maximum production for fish populations. This can be particularly serious if low flows are combined, as they often are, with high water temperatures or with water of poor quality.

Radford (1975) points out that, during the first few years after closure, when large amounts of organic material are decomposing, considerable quantities of ammonia and hydrogen sulphide, both toxic to fish, are produced in the bottom waters of lakes, and oxygen is depleted. Major fish kills can occur if such water is released downstream as a slug. He reports that fish kills of this kind have occurred downstream of Waterton Reservoir.

In the absence of fish passage facilities, some species are prevented from completing their traditional migrations to and from critical spawning, rearing, and feeding areas. Populations of such species are either severely reduced or eliminated. Down stream of the St. Mary and Waterton reservoirs, populations of cutthroat trout, rainbow trout, and Dolly Varden have been eliminated, while populations of northern pike and mountain whitefish have increased, perhaps in response to the elimination of the competing salmonid species (Radford 1975).

Where fish populations still retain a tendency to move upstream, they often concentrate downstream of dams. Clements (1974) remarks heavy fishing pressure in the pool below the spillway on the Waterton River.

5.6 POTENTIAL IMPACTS ON WILLOW CREEK/PINE COULEE FROM RESERVOIR DEVELOPMENT

This section is a review of the potential impacts of reservoir development on Willow Creek, with an emphasis on how fish populations in this stream might be affected.

5.6.1 Upstream of the Impoundments

Some upstream changes in fish populations could occur as the result of construction of an impoundment on Willow Creek. For example, an upstream extension of the ranges of northern pike, emerald shiner, spottail shiner, northern redhorse sucker, and burbot is possible. All of these species occur in Reaches B and C, but are now rare or absent in Reach A (Table 5-3). Upstream extension of the ranges of these species might result from reservoir construction at Sites 1, 2 and 4.

5.6.2 Within the Impoundments

5.6.2.1 Fish Production. Without any detailed information on the morphometry of the proposed reservoirs, or on their use and operations, it is not possible to make any precise predictions of their potential for fish production. Some general assessments can be made, however, first by comparing the characteristics of the proposed reservoirs to those of other existing reservoirs in southern Alberta; and, second, by examining the history of fisheries in Chain Lakes Reservoir, a body of water in the same drainage as the proposed reservoirs.

Table 5-5 summarizes information describing selected characteristics of 15 reservoirs in southern Alberta, and compares these data to comparable data for the four reservoirs proposed for Willow Creek. The table includes a relative index of fish production, the Morphoedaphic Index (MEI)(Ryder 1965), defined as Total Dissolved Solids concentration (ppm/mean depth [ft.]), as well as an estimate of potential fish production based on the MEI, defined as 2 $(MEI)^{1/2}$.

The data indicate that the values for the MEI for the four proposed resevoirs (3.8 to 9.3) are lower than the average of the 15 existing reservoirs (28.1), and that, as a consequence, estimated fish production (3.9 to 6.1 kg/ha/yr)is also lower than the average of the existing reservoirs (9.4 kg/ha/yr). Of the four reservoirs, the potentially most productive of fish is Site 4 (combining the mainstream and Pine Coulee), followed in order by Site 2 (offstream in Pine Coulee) and the mainstem reservoirs at Site 1 and Site 3. Even for Site 2, however, values for the MEI and estimated fish production are exceeded by values for 9 of the 15 existing reservoirs included in the sample.

Table 5-5 also includes data describing commercial fish production on reservoirs during the five-year period from 1980 to 1984. It should be emphasized, however, that the productivity of lakes as indicated by commercial catches cannot be related to any single characteristic (e.g. MEI, shoreline development, flushing rate). Most of the reservoirs were constructed with the primary purpose of storing irrigation water, and conditions in them are generally more variable than those in natural lakes of comparable size. The operating characteristics vary from year to year, depending on weather conditions and water demand, and cover a wide range.

In situations where water management involves practices which are detrimental to fish (e.g. great fluctuations in water level), populations may be reduced or even eliminated. An extreme example is Keho Lake where, in the winter of 1970/1971, a drawdown undertaken to effect repairs in the vicinity of the headgate is

Table 5-5 Data describing fisheries-related characteristics of 15 reservoirs in Alberta and comparable data for four proposed reservoir sites on Willow Creek. Data from various sources including Fish and Wildlife Division Files, Lethbridge; Alberta Environment Planning Division, and McCart (1978).

NAME	AREA (ha)	VOLUME (m x 10)	DEPTH(m) MEAN	MAX	FLUSHING RATE (TIME/YR)	MEAN TDS (ppm)	M.E.I.	COMMERCIAL FISH PROD. (kg/ha/yr) Estimated	Actual (1980-1984)
Chain Lakes	321	17.3	5.4	9.1	-	187	10.6	6.5	-
Fincastle	202	4.2	2.7	6.1	21.8	386	43.9	13.2	13.1
Jensen	183	18.7	10.2	30.8	15.0	312	9.3	6.1	0.2
Little Bow	748	39.2	5.2	14.0	6.0	420	24.6	9.9	8.9
Murray	1668	30.8	1.8	7.3	-	262	44.4	13.3	0.9
Rattlesnake	152	7.9	5.2	22.0	8.0	382	22.3	9.4	8.6
Ridge	1533	128.6	8.5	16.4	-	220	7.9	5.6	-
Scope	809	17.3	2.1	12.8	3.0	404	58.5	15.3	1.9
Sherburne	449	30.8	7.6	15.2	0.4	420	16.9	8.2	47.7
Stafford	263	11.6	4.4	6.7	17.0	420	25.3	10.1	10.5
St. Mary	3539	370.0	10.5	51.1	5.0	228	6.6	5.1	2.6
Taber	395	6.4	1.6	4.6	2.0	684	131.5	22.9	-
Travers	2235	324.4	14.5	39.0	0.7	430	9.0	6.0	3.5
Upper Chin	1635	206.1	13.2	20.1	-	348	8.0	5.7	<0.1
Waterton	1066	171.7	16.1	48.3	7.2	187	3.5	3.7	-
Mean	1013	92.3	7.3	20.2	8.2	353	28.1	9.4	8.9
Site 1	285	39.0	13.7	27	1.4	250	5.6	4.7	-
Site 2	540	50.5	9.4	21	0.8	275	8.9	6.0	-
Site 3	295	59.0	20.0	46	1.6	250	3.8	3.9	-
Site 4	885	72.6	8.2	23	1.5	250	9.3	6.1	-

thought to have entirely eliminated the fish fauna. It is probably significant that Sherburne Lake, which has consistently produced the largest catches in the area (47.7 kg/ha/yr, far in excess of its estimated total fish production of 8.2 kg/ha/yr) is a special purpose reservoir, the primary function of which is to store excess water for later use. It has a low flushing rate (0.4 times/yr), and water levels are generally more stable than those of other reservoirs.

Chain Lakes Reservoir is located within the Willow Creek Drainage upstream of the four proposed reservoirs, and provides an instructive example of what might happen in reservoirs further downstream. The reservoir was filled for the first time in 1966. It has a larger area than two of the proposed reservoirs, but is shallower and has a smaller volume than any of the four (Table 5-5). Its Total Dissolved Solids content is lower than that predicted for the four reservoirs downstream, but its MEI (10.6) and its estimated fish production (6.5 kg/ha/yr) are both higher.

Thirteen species of fish have been reported from the reservoir itself (Table 5-3), including five species of sports fish (mountain whitefish, together with the cutthroat, rainbow, brook, and bull trout), four species of minnows, three species of suckers, and the spoonhead sculpin. No cool water sports fish (e.g. northern pike, walleye, and perch) have been reported in the reservoir. Rainbow trout have been planted in the lake since 1967. Walton (1980) reports an additional two species, the brown trout and brook stickleback, from Chain Lakes Reservoir and Upper Willow Creek combined. These may be confined to the stream and absent or rare in the reservoir.

MacNeill (1978) assessed the progress of the sports fishery in Chain Lakes Reservoir through 1978. He found that the proportion of sports fishes in test catches had declined, while those of suckers, principally the white sucker (93.6% of the suckers in Upper Willow Creek were the latter species - Walton 1980), had increased (Table 5-6) so that in most years after 1970, they constituted 80 to 90 % of test catches. Some sports species seemed to have disappeared, and

Table 5-6 Species composition of fishes taken in test gillnets, Chain Lakes Reservoir, 1968-1978. N.D. indicates no data for that year. Data from MacNeill (1978).

YEAR	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Sample Size (n)	50	152	145	146	1169	1118	N.D.	698	N.D.	279	35
% Composition											
Mountain Whitefish	20	1		1	1			1			
Cutthroat Trout		1									
Rainbow Trout	20	34	16	9	14	11		6		23	51
Brook Trout	22	1			1						
Bull Trout		5		3							
Suckers	40	58	84	87	86	89		93		77	49

only the rainbow trout, which had been planted in large numbers (Table 5-7), continued to be common. At the same time, however, the growth of rainbow trout declined. Between 1972 and 1977, for example (Table 5-8), the mean fork length of rainbow trout at age 2 fell from 335 mm to 191 mm (to 57% of the earlier value), and mean weight from 439 g to 90 g (to 20.5% of the earlier value).

Attendance at Chain Lakes Provincial Park also declined over the period of 1972 - 1977 (Table 5-9). By 1977, attendance was only 55% of the six year mean, and 37.6% of the peak year in 1974. MacNeill (1978) suggests that the decline in attendance was the result of smaller fish and poorer fishing success.

Walton (1980) discussed the reasons for the success of white suckers in Chain Lakes Reservoir. He suggested that this species was generally better adapted to reservoirs than the related longnose sucker. Where the two species co-exist in reservoirs, the former generally predominates. This may be related to differing adaptation to standing waters, to differences in tolerance of fluctuating water levels, to differences in temperature tolerance, and to differences in food habits. Walton (1980) did not feel that in the Chain Lakes Reservoir the most abundant predator, the rainbow trout, provides any effective control on the abundance of suckers. It has been suggested (Laglen 1956) that the success of suckers in impoundments may degrade sports fisheries but this cannot be conclusively established for the Chain Lakes Reservoir.

The information included in Section 5.5.2.3 and the more specific information included here suggest that, in any of the four impoundments in the Willow Creek Drainage, we can expect a short-term period of one or two years during which fish production will be relatively high, followed by a period during which production of both fish food organisms and fish undergo a drastic decline. This will be reflected in the growth of individual fish and in the availability of fish to fishermen.

Table 5-7 Plants of rainbow trout in Chain Lakes Reservoir, 1967-1977. Data from MacNeill (1977)

YEAR	NUMBERS	SIZE
1967	320,200	Fingerlings
1968	589,250	Fingerlings
1969	700,740	Fingerlings
1970	713,600	Fingerlings
1971	365,075 245,800	Fingerlings Yearlings
1972	385,000	Fingerlings
1973	401,650	Fingerlings
1974	397,000	Fingerlings
1975	403,991 39,835	Fingerlings Yearlings
1976	397,000	Fingerlings
1977	60,200	Yearlings

Table 5-8 Length and weight of Age 2 and 3 rainbow trout. Data for Chain Lakes Reservoir from MacNeill (1978), for Willow Creek, Reach A, from English (1984).

		AGE 2			AGE 3		
SOURCE	YEAR	N	MEAN LENGTH(mm)	MEAN WEIGHT(g)	N	MEAN LENGTH(mm)	MEAN WEIGHT(g)
Chain Lakes	1972	65	335	439	-	-	-
	1977	44	191	90	15	252	180
Willow Creek, Reach A	1981	32	155	53	10	229	167

Table 5-9 Chain Lakes Provincial Park Estimated Attendance Figures. Figures are from April 1 through October 31 each year. From McNeill (1978).

YEAR	ESTIMATED ATTENDENCE
1972	94,504
1973	90,316
1974	120,380
1975	81,804
1976	59,384
1977	45,282
MEAN	81,945

Ultimately, the reservoirs would be expected to be characterized by a relatively low production of fish, compared with most other reservoirs in southern Alberta. Of the four, Site 4 (Pine Coulee/Willow Creek) would be expected to have the highest production, followed in order by Site 2, Site 1 and Site 3.

5.6.2.2 Species Compostion. Table 5-10 presents data describing the distribution of fish species in 21 reservoirs in southern Alberta. Four species, the lake whitefish, the longnose and white suckers, and the northern pike occur in almost all the of the reservoirs. Another common species, the burbot, has been reported from 15 reservoirs. Other than the lake whitefish, which has been artificially introduced into many of the reservoirs, all of these widely distributed species have entered the reservoirs naturally, either from the streams dammed to form the reservoirs, or through the irrigation systems.

Overall, it would appear that conditions in reservoirs in southern Alberta are generally unsuitable for the development of populations of cold water sports fishes. They persist only in the larger mainstem reservoirs and even there, populations are small. Elsewhere, natural reproduction is generally absent and small populations are maintained by regular planting of hatchery fish.

Of the cool water sports species inhabiting reservoirs in southern Alberta, the northern pike has been most successful, entirely as the result of natural propagation. The walleye, the second most important cool water sports species in reservoirs, has been much less successful in establishing persistent populations. It appears to have a limited capacity to colonize new habitats within the irrigation system and has only become well established (e.g. St. Mary, Upper Chin, Sherburne, Travers) where artifical propagation, generally through the planting of fertilized or eyed eggs, has been practiced.

Yellow perch, like the related walleye, appear to be very slow to colonize new habitat. There seem to have been no attempts to propagate this species artificially. The burbot, which is sometimes

Table 5-10 Presence of fish species in 21 reservoirs in southern Alberta and in or upstream of proposed reservoir sites on Willow Creek. Asterisk indicates present, dash indicates absent.

	RECORDED LOCATIONS		SPECIES REPORTED IN OR UP STREAM OF			
	N	%	SITE 1	SITE 2	SITE 3	SITE 4
Kokanee	1	5	-	-	-	-
Lake Whitefish	20	95	-	-	-	-
Mountain Whitefish	2	10	*	*	*	*
Cutthroat Trout	2	10	*	*	*	*
Rainbow Trout	9	43	*	*	*	*
Brown Trout	2	10	*	*	*	*
Brook Trout	1	5	*	*	*	*
Bull Trout	1	5	*	*	*	*
Lake Trout	2	10	-	-	-	-
Northern Pike	20	95	*	*	-	*
Lake Ehub	5	24	*	*	*	*
Emerald Shiner	2	10	*	*	*	*
Spottail Shiner	6	29	*	*	-	*
Fathead Minnow	5	24	*	*	*	*
Pearl Dace	1	5	-	-	-	-
Longnose Dace	3	14	*	*	*	*
Longnose Sucker	16	76	*	*	*	*
White Sucker	18	86	*	*	*	*
Mountain Sucker	1	5	*	*	*	*
Northern Red-horse Sucker	2	10	*	*	-	*
Burbot	15	71	*	*	-	*
Brook Stickle/back	0	0	*	*	*	*
Trout-perch	5	24	*	*	*	*
Spoonhead Sculpin	1	5	*	*	*	*
Valleye	13	62	-	-	-	-
Yellow Perch	8	38	-	-	-	-

classified as a sports fish, is like the northern pike in that it appears to be extremely mobile and is found in almost all of the reservoirs examined.

The lake whitefish, a species found in nearly all of the reservoirs included in Table 5-10 (Chain Lakes is the exception), is generally thought of as a cold water species, but has a much wider tolerance of environmental extremes than most species in this group. The species is occasionally angled, but its major importance is in commercial fisheries. The species was planted in many of the reservoirs in the area. It is a very mobile species, and has invaded other reservoirs by moving downstream. In some reservoirs, the lake whitefish is occupying marginal habitat, and populations have suffered collapse when local weather or the operation of the reservoir have resulted in adverse temperature and oxygen conditions.

The information in Tables 5-3 and 5-10 can be used to predict those species most likely to occur in each of the four reservoirs proposed for Willow Creek. There are three premises:

1. There will be no planting of species (e.g. lake whitefish) which do not already occur in the Willow Creek Drainage;
2. The only species which will enter reservoirs are those which have been reported within the reach to be impounded or upstream of the reach;
3. The species most widely distributed in other reservoirs in southern Alberta are also those most likely to become established in any impoundment on Willow Creek.

With regard to the latter, species which occur in 70% or more of existing reservoirs in southern Alberta (Table 5-10) were considered to have a high probability of occurring in the four Willow Creek Reservoirs as well; while fish which occur in 20 to 70% of existing reservoirs and which also occur in Chain Lakes Reservoir upstream were considered to have a moderate probability.

Using these criteria, it was judged that nine species (four with a high and five with a moderate probability of occurence) were likely to occur in impoundments at Sites 1, 2 and 4, while only six were likely to occur at Site 3 (Table 5-11). The latter site is upstream of the known distribution of the three absent species (northern pike, burbot, and spottail shiner). Of the listed species, only three (northern pike, burbot, and rainbow trout) are sports species. In fact, the probability that the latter species will become established as a thriving, self-reproducing population without the planting of hatchery-reared fish is quite low.

It is likely that in each of the four sites, the fish fauna will be dominated by white suckers as is that of Chain Lakes Reservoir further upstream (MacNeill 1978; Walton 1980). The most common sports species will be the northern pike and burbot at Sites 1, 2 and 4. At Site 3, the only sports species which will occur is the rainbow trout since neither northern pike nor burbot are known to occur in the reach included in the impoundment or upstream. It should be noted that the distribution records may not be entirely accurate, and either species may occur rarely (though neither apparently occurs in Chain Lakes Reservoir). If so, they may gain access to Site 3 and, once there, would be expected to do well.

5.6.2.3 Fisheries. In southern Alberta, there is considerable local recreational fishing, particularly on the smaller, less windy, reservoirs. The species most frequently sought by anglers are rainbow trout, where these are stocked during the early flush of productivity which follows immediately after impoundment; and, later, northern pike and walleye, after productivity has stabilized at a lower level.

Without stocking, sports fisheries on the four Willow Creek reservoirs would be expected to develop slowly. At Sites 1, 2 and 4 northern pike and burbot would provide the bulk of the fishery. At Site 3, where neither pike nor burbot apparently occur, the only sports species present are cold water fishes, principally the rainbow

Table 11 Fish species with high to medium likelihood of becoming established in reservoirs at four sites on Willow Creek in the absence of stocki

	SITE 1	SITE 2	SITE 3	SITE
		High Probability		
Northern Pike	*	*	-	*
Longnose Sucker	*	*	*	*
White Sucker	*	*	*	*
Burbot	*	*	-	*
		Medium Probability		
Rainbow Trout	*	*	*	*
Lake Chub	*	*	*	*
Spottail Shiner	*	*	-	*
Fathead Minnow	*	*	*	*
Trout-Perch	*	*	*	*
TOTALS	9	9	6	9

trout. Rainbow trout, though they might occur, especially early in the life of each of the reservoirs, are unlikely ever to be abundant.

With stocking, each of the reservoirs would likely provide excellent rainbow trout fishing for the first few years after initial flooding followed by a rapid decline. Walleye would only occur as the result of stocking, and even then it is not certain that they would become permanently established.

There are commercial fisheries on many of the irrigation reservoirs in southern Alberta (Table 5-5). By far the most important species taken in the commercial fishery is the lake whitefish, which generally makes up over 80% of the total catch by weight. Typically, the season (spring, fall, or winter, depending on the reservoir) and other aspects of the commercial fisheries on reservoirs are designed to facilitate the capture of the lake whitefish and to minimize mortality to pike and walleye which are important sports species. Whitefish in the area are small to medium-sized, and few jumbos are taken. They are of high quality (Triaenophorus infestations are non-existent), and there are no taste problems. Most are sold in the Lethbridge area, but a small percentage is marketed in Calgary.

Other than lake whitefish, the species taken in the commercial fishery include, in order, suckers (longnose and white combined), pike, burbot, and walleye. Trout and yellow perch are minor components confined to a few lakes each.

Since commercial fisheries in southern Alberta occur only where there are substantial numbers of lake whitefish available for harvest, there is unlikely to be any commercial exploitation of the reservoirs unless this species is present. Lake whitefish are not now present in the drainage, and will not occur in any of the four Willow Creek Reservoirs unless stocked. If stocked with lake whitefish, the reservoirs would be expected to provide a relatively low yield commercial fishery, in the range of 3 to 6 kg/ha/yr, consisting, in order, of lake whitefish, suckers (principally white), northern pike, and burbot at Sites 1, 2 and 4. Only the first two species would occur at Site 3.

As already indicated, the most productive reservoir for both recreational and commercial fisheries would be expected to be at Site 4, and the least productive at Site 3.

5.6.3 Downstream of the Impoundments

5.6.3.1 Changes in Seasonal Pattern of Discharge. At present the major problem for fish populations downstream of the impoundments is reductions in discharge. English (1984) notes that there is an extremely high demand for water, for both domestic use and irrigation, in the Willow Creek Drainage, and low discharges are a chronic threat to the fishery in Willow Creek. Winter flows are commonly too low, and in some years (e.g., in the winters of 1981/1982 and 1984/1985) flows nearly cease and winter kills of fish occur. There is also a potential for summer kills during periods of low discharge and high water temperatures.

Any reservoir on Willow Creek will be designed to trap spring runoff so that flows downstream can be augmented during summer and winter when flows are now very low. Tennant (1976) has provided some guidelines concerning streamflow requirements downstream of impoundments. His "Montana Method" is outlined in Table 5-12. At a minimum, to provide any fishery at all, the operational regime should provide at least 10% of mean annual natural flow during both the October through March and April through September periods.

Regarding this minimum standard, Tennant states that:

> This is a minimum instantaneous flow recommended to sustain short-term survival habitat for most aquatic life forms. Channel widths, depths, and velocities will all be significantly reduced and the aquatic habitat degraded. The stream substrate or wetted perimeter will be about half exposed, except in wide, shallow riffle or shoal areas where exposure could be higher. Side channels will be severely or totally dewatered. Gravel bars will be substantially dewatered and islands will usually no longer function as

Table 5-12 Instream flow regimes for fish, wildlife, recreation, and related environmental resources. From Tennant (1976). Flows are expressed as % average annual flow under natural conditions.

Narrative Description of Flows	Recommended Base Flow Regimes Oct.-Mar.	Apr.-Sept.
Flushing or maximum	200%	200%
Optimum range	60-100%	60-400%
Outstanding	40%	60%
Excellent	30%	50%
Good	20%	40%
Fair or degrading	10%	30%
Poor or minimum	10%	10%
Severe degradation	0- 10%	0- 10%

> wildlife nesting, denning, nursery, and refuge habitat. Streambank cover for fish and fur animal denning habitat will be severely diminished. Many wetted areas will be so shallow they no longer will serve as cover, and fish will be crowded into the deepest pools. Riparian vegetation may suffer from lack of water. Large fish will have difficulty migrating upstream over riffle areas. Water temperature often becomes a limiting factor, expecially in the lower reaches of streams in July and August. Invertebrate life will be severely reduced. Fishing will often be very good in the deeper pools and runs since fish will be concentrated. Many fishermen prefer this level of flow. However, fish may be vulnerable to over-harvest. Floating is difficult even in a canoe or rubber raft. Natural beauty and stream esthetics are badly degraded. Most streams carry less than 10% of the average flow at times, so even this low level of flow will occasionally provide some enhancement over a natural flow regimen.

With respect to Tennant's last point, the present flow regime in a large portion of Willow Creek is not natural, as the result of the operation of the Chain Lakes Reservoir. A 10% standard might actually improve conditions for fish in some stretches of the creek, in years such as 1981/1982 and 1984/1985, when flows in parts of the drainage ceased. The 10% standard would have supplied a minimum flow to the stream, and would presumably have reduced the severity of the fish kills which occurred during these winters.

Tennant makes one other very important point which has application to the reservoirs proposed for Willow Creek. That is, that discharge criteria must be defined in terms of instantaneous flows and not averaged over a day, month, or year, permitting erratic releases or even no flow at times. If, for example, the criterion is 10% of mean annual flow, at no time should the discharge fall below this level. Large numbers of fish might be stranded and killed if the flow were substantially reduced or ceased for even a few hours.

Chain Lakes Reservoir was constructed on Willow Creek to provide water shortage facilities which could augment flows in Willow Creek during dry spells, or high water demand seasons. The total annual discharge into Willow Creek has probably not changed much, since there are no diversions out of the drainage, but the seasonality of discharge has undoubtedly been affected.

The mean annual discharge at Claresholm is now 3.35 m^3/sec; the mean discharge for the April through September period is 5.67 m^3/sec; and the mean discharge for the October through March period is 1.03 m^3/sec. Fifty-two percent of the total annual discharge occurs during the months of May and June. Mean monthly discharges all exceed 10% and most exceed 20% of mean annual discharges (exceptions are December and January). All mean monthly discharges during the April through September period exceed 40%, and all except one (September) exceed 50% of mean annual discharge.

These values would suggest that the stream should represent fair to good fish habitat from the point-of-view of flow regime. In fact, the stream is considered by fisheries biologists to be relatively poor fish habitat, largely as the result of intermittent low flows. The situation in the stream is a good example of Tennant's point that discharge data averaged over a long enough period can mask conditions which have a serious adverse effect on fish populations and other aquatic resources.

The four reservoirs would presumably serve the same uses and have roughly comparable operational and discharge regimes. With regard to potential impacts downstream, the major differences among them would appear to be related to the length of stream which might be affected (i.e., the further upstream the reservoir outlet, the greater the potential effects). If the reservoirs are operated to provide acceptable instantaneous flows, the impact on fish populations downstream may very well be positive.

5.6.3.2 Effects on Migration. In the absence of fish passage facilities, some species are prevented from completing their traditional migrations to and from critical spawning, rearing, and feeding areas. Populations of such species are either severely reduced or eliminated. Downstream of the St. Mary and Waterton reservoirs, populations of cutthroat trout, rainbow trout, and Dolly Varden have been eliminated while populations of northern pike and mountain whitefish have increased, perhaps in response to the elimination of the competing salmonid species (Radford 1975).

Where fish populations still retain a tendency to move upstream, they often concentrate downstream of dams. Clements (1974) remarks the heavy fishing pressure in the pool below the spillway on the Waterton River.

Little is known of the migration of fish in Willow Creek but there are undoubtfully some movements which might be interrupted by the construction of dams or rivers. A fish ladder has been included in the conceptual design for the diversion weir associated with the reservoir at Site 2 (N. Neimer, Alberta Environment, pers. comm.). There are at present no conceptual designs for the other three sites but since they will probably involve high dams and not low head weirs, fish passage facilities may be impractical.

There is one other related problem that deserves mention. That is that fish are often attracted to fast water immediately downstream of dams and at the mouths of diversions because temperatures are more satisfactory or because food is abundant. Such concentrations may be subject to high mortality rates either from predation or from angling. This situation could arise downstream of the dams proposed at Sites 1, 3 and 4 or downstream of the diversion weir proposed at Site 2. At Site 2, however, there may be an additional concentration of fish at the outflow of the reservoir where diverted water re-enters Willow Creek.

5.7 COMPARISON OF RESERVOIR SITES

Table 5-13 ranks the reservoir sites with regard to factors potentially affecting fish populations and fisheries potential. The following brief notes outline the rationale for ranking each factor.

1. Morphoedaphic Index: The higher the MEI (from Table 5-5), the greater the potential productivity of fish populations.

Table 5-13 Ranking of four reservoir sites with regard to factors affecting fish populations and fisheries potential. (Designation 1 indicates most favorable conditions, 4 indicates least favorable).

	SITE 1	SITE 2 (indicating diversion weir)	SITE 3	SITE 4
A) POTENTIAL FOR RESERVOIR FISHERY				
Morphoedaphic Index	3	2	4	1
Favorable Flushing Rate	2	1	4	3
Potential for:				
recreational fishery	3	2	4	1
commercial fishery	3	2	4	1
B) IMPACTS TO EXISTING FISHERY				
Effects on Existing Stream Habitat	2	1	4	3
Potential for:				
Blockage to Migration	4	3	1	2
Potential for Adverse Effects Downstream	1	2	4	3
Mean Rank	2.6	1.9	3.6	2.0

2. Flushing Rate: The lower the flushing rate and the lower the fluctation in water levels, the greater the fisheries potential.

3. Potential for recreational fishery: Related to MEI, but influenced by the likelihood of establishment of species exploited by anglers (Table 5-11).

4. Potential for commercial fishery: based on values for estimated commercial fish production (Table 5-5).

5. Effects on existing stream habitat: Reservoir flooding at Site 3 will eliminate some of the best habitat for stream-dwelling cold water sports species in the drainage. In contrast, habitat at Site 2 is only marginal at present.

6. Blockage to migration: There are no good data on migration patterns of fish in the drainage, and this assessment is largely a relection of the premise that the lower the location of the dam or diversion works in the drainage, the larger the area upstream denied to migrating fish.

7. Potential for adverse effects downstream: The reverse of the statement above. The higher the location of the reservoir in the drainage, the greater the potential for adverse effects downstream, assuming similar discharge patterns.

Some of the points above may be much modified as more information becomes available concerning the reservoirs (their morphology, their design, the uses for which the water is intended, and their operating characteristics) and the life histories of fish populations in the drainage. Nevertheless, there is a clear preference for Sites 2 or 4, from the point-of-view of fisheries. In contrast, it is equally clear that Site 3 is the least satisfactory of the four sites.

With a reservoir at either Site,2 or Site 4, new fish habitat would be created in Pine Coulee where little now exists. The major differences between the two sites are first, that the latter would involve a high dam rather than a low diversion weir, and second, that it would flood a portion of Willow Creek not affected by a reservoir at Site 2. The high dam might preclude fish passage facilities such as fish ladders. This might be an important difference if future studies indicate that important migrations of fish occur through this reach. For this reason, Site 2 would be preferable to Site 4.

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6.0 GEOLOGY, SOIL AND LAND USE

6.1 Component Requirements

Geology and Soils

1. Provide a brief description of the geology and soils of the four sites;
2. Identify any existing erosion problems and assess the erosion potential of the soils; and
3. Discuss any significant reclamation problems that might be presented by the soils.

Land Use

1. Describe and map land use at the three sites; and
2. Discuss the potential effects on land use of constructing a reservoir at each of the sites.

6.2 METHODS

6.2.1 Geology Information Review.

Geology of the potential sites was described using existing maps and reports and photo interpretation. Sources of geologic information that were reviewed included: (1) maps and reports from the Geological Survey of Canada and other sources; (2) geological discussions presented in Canada Land Inventory Soil Capability for Agriculture Maps (82G, H, I, J); (3) existing soil survey maps and reports (see soils discussion below); (4) air photo interpretation; and (5) a field visitation.

Major landforms generally have predictable kinds of materials, vegetation and/or climate, drainage and stability. These major landforms can be subdivided and their surficial geological characteristics separated into:

1. Glaciofluvial terraces, eskers, kames and outwash channels, comprised of coarse gravels and sands;

2. Creek terraces and floodplains with moderately fine alluvium as parent materials, with minor inclusions of coarse-textured materials (postglacial in origin);
3. Colluvial slopes and fans, having a heterogeneous mixture of parent materials variable in texture, size of fan, steepness of slope and time of deposition (all are postglacial in origin - some may still be aggrading);
4. Moraines composed of medium to fine-textured glacial till materials. Morainal landforms will be primarily ground moraines although the possibility exists for drumlins, and lateral and end moraines.

Specific landforms found at the four proposed sites were largely described as above through air photo interpretation and mapped using the biophysical legend in Appendix III. Some verification was undertaken during the field visitation.

6.2.2 Soils Information Review

Site-specific soils information for the Willow Creek basin and the four potential reservoir sites was available from:

1. Canada Land Inventory Soil Capability for Agriculture maps 82G, H, I and J;
2. Alberta Government/Canada Department of Agriculture Soil Survey Map Sheets 1 (Macleod Sheet), 9 (Lethbridge and Pincher Creek Sheets - Bull. No. 32), and 11 (Blackfoot and Calgary Sheets - Bull. No. 22);
3. Provincial park soil surveys for the Willow Creek and Chain Lakes Provincial Parks;
4. An Alberta Environment Resource Evaluation and Planning Division report;
5. University graduate student theses;

6. Air photo interpretation; and

7. Field visitation.

Because of a paucity of site-specific data, most soils information was extrapolated from the existing soil surveys, through air photo interpretation and the field visitation.

Susceptibility of soils to erosion depends on slope, vegetation cover, soil texture, structure, organic matter content, depth, moisture content and compaction. Of primary relevance to this study are the parameters of slope stability, maintenance of vegetation cover and slope/aspect effects on soil depth, development and relative aridity. These parameters were assessed during the field visitation and from aerial photography interpretation. Results are discussed in Section 6.3.1.2 for each potential reservoir site.

Geotechnical stability was assessed from the aerial photography and to a lesser extent during the field survey. Slope, aspect,, parent material and specific soil characteristics (such as topsoil depth and texture, and salinity) were several reclamation parameters that were evaluated. Results obtained are discussed by potential reservoir site in Section 6.3.1.2.

6.2.3 Land Use

Land use at the three proposed reservior sites was mapped from the most recent (spring 1984 - 1:20 000 scale) black and white aerial photography, and land ownership was determined from Municipal District Maps. This, along with the ground verification provided the most up-to-date data base. Recreational use of Willow Creek Provincial Park was also assessed from Park's records (Alberta Recreation and Parks 1984).

6.2.4 Photo Interpretation and Mapping

The 1984, 1:20,000 scale black and white aerial photography was the primary remote sensing data source.

Soils, surficial geology/geomorphology and land use were mapped onto photo overlays using a Wild Heerbrugg Mirror Stereoscope, with 3-power oculars. A suitable and approved biophysical legend was specifically developed for this task (Appendix III). This information was then transferred onto overlays registered to the appropriate photo-mosaic/base maps using a Bausch and Lomb stereo zoom transferscope.

Base maps consisted of semi-controlled; 1:20,000 scale mylar air photo mosaics, provided by Alberta Environment. The results of this mapping exercise were three maps illustrating surficial geology, vegetation, soils and land use (inferred from land cover type) for the four potential reservoir sites (see map pocket on back cover of report).

6.3 RESULTS AND DISCUSSIONS

6.3.1 Geology and Soils

6.3.1.1 Geology. The physical geology and geomorphology of the Willow Creek study area have been studied and reviewed by a number of scientists over the past few decades. The area was glaciated by both the Laurentide and Cordilleran ice sheets, as evidence by the presence of both granite and limestone erratics within the glacial tills overlying the bedrock (Crack and Danielson, 1974).

The Laurentide ice moved into, around and through the Porcupine Hills from the north, east and south with glacial tongues wedging up the valleys of Trout and Willow Creeks to spill over into the Oldman River basin (Beaty 1975). Cordilleran mountain ice flowed through the "Gap" of the Oldman River in the Livingstone Range and brushed the western flank of the Porcupine Hills at least once. Beaty (1975) identified Pine Coulee as one of three glacial meltwater channels perched on the side of the Hills that actually run across the edge of the topographic highlands, rather than down the regional slope. The presence of the Laurentide ice sheet to the immediate east, with the hills to the west, forced the water to flow along and perhaps underneath the ice edge in a southerly direction. According to Beaty (1975), the ice edge "must have been highly irregular in conformity with the underlying terrain, and the sinuous meltwater streams, trapped between the glacier and the slope of the Hills, simply cut down in place, thus producing large channels". The rather smooth ground moraine is thus dissected by this glacial meltwater channel, as well as several more recent fluvial erosional channels and numerous bedrock outcrops along same.

Irish (1968) indicates that the geology of the study area generally consists of Tertiary and Cretaceous sandstones and shale of the Willow Creek, Paskapoo and/or Porcupine Hills Formations. According to Green (1972), the Paleocene (Tertiary) Porcupine Hills Formation is nonmarine, consisting of "pale grey, thick-bedded, cherty, calcareous sandstone and pale grey calcareous mudstone". The Willow Creek Formation is Paleocene and Upper Cretaceous in age, and is composed of nonmarine sediments, consisting of "pale-grey, fine-grained calcareous sandstone, thick bedded and coarse-grained in the upper part; grey, green and pink bentonitic mudstone with abundant white-weathering calcareous concretions; and scattered thin limestone beds". The Paskapoo Formation is also of Paleocene and Upper Cretaceous origin, and is comprised of "grey to greyish green, thick-bedded, calcareous, cherty sandstone, thin limestone, coal and tuff beds". From this discussion, the geologic overlap between these formations becomes obvious.

Some difference in opinion exists as to the correct nomenclature used in describing the area. Douglas (1950) described the geology of this area as the Porcupine Hills Formation, and this formation only occurred in the "immediate vicinity" of the Porcupine Hills, bounded on east, west and south by the abrupt boundary of the Willow Creek Formation and to the north by the contemporaneous Paskapoo Formation. Tozer (1956) maintained that the Porcupine Hills Formation lies between the Oldman River in the south, and Township 13 in the north. This indicates that the boundary between the Porcupine

Hills and Paskapoo Formations lies in the area of the four potential reservoir sites; Tozer (1956) qualified that the boundary is, however, diffcult to define. He also noted that the Willow Creek Formation cuts through the Porcupine Hills Formation in the form of two belts of outcrop; one on the east and one on the west of the Alberta Syncline. Irish (1968) shows the geology at the potential reservoir sites to be Paskapoo Formation, with numerous rock outcrops of this type occurring at both the Pine Coulee and Willow Creek sites. In contrast to this, Carrigy (1970) contended that the geology in the area is Porcupine Hills Formation and that this young formation overlies the Paskapoo Formation as far north as the Red Deer River. Day (1971) characterized the structure of the Porcupine Hills Formation as being a "west-facing cuesta, the strata of which dip toward the south and east". Green (1972) classified the bedrock at the Pine Coulee and Kuntz Creek sites as Porcupine Hills Formation, while that of the Willow Creek site appears to be a transition from Porcupine Hills Formation in the west, to Willow Creek Formation in the east.

6.3.1.2 Soils. Soils of the Willow Creek study area generally developed on glacial till, glacio-fluvial or fluvial sediments. Soil orders expected at the four potential reservoir sites include primarily Chernozems, Regosols, and Luvisols, with Brunisols and Gleysols also possible. While very little or no specific soil survey data is available for the four potential sites, with the exception of a survey of a portion of the Willow Creek and Pine Coulee/Willow Creek sites by Greenlee (1983), several soil survey analogues could be found.

Studies by Mee (1971), Alberta Energy and Natural Resources (AENR-1979), and Greenlee (1985) provide useful soils information for the western-most potential reservoir site (Willow Creek at Kuntz Creek). Soils of this site were expected to follow the sequence described by Mee (1971). Parent material, slope, aspect and vegetation are predominant factors affecting soil development. Luvisols are dominant on the more stable north-facing slopes, while

Brunisols might be found less commonly on steeper slopes of this aspect. South aspect slopes more closely reflect vegetation/micro climatic variations; (calcareous) Chernozems are likely found under grassland, degraded Chernozems under aspen, and "youthful Grey Wooded" soils under lodgepole pine and/or Douglas Fir. This general picture is appropriate for 4,000 to 5,000 ft. elevations, with Chernozems more common below this range and Luvisols more common at higher elevations. It was also noted that Gleysols might occur in seep areas and Regosols in very steep sloped areas. The AENR report (1979) indicated that the most common soil subgroup for this western area would be Orthic Black Chernozems with the Calcareous subgroup also occurring. These sola range in depth from 25 to 40 cm, are fine-textured loams and are well to moderately well-drained. Cobbles are very abundant in these profiles. The floodplain at this potential reservoir site (Site 3) would likely possess soils of Chernozemic or Regosolic orders, depending on degree of erosion, previous disturbance and drainage. The wettest sites may have various types of wet soils such as Humic Regosols (AENR 1979).

A soil survey completed for the Willow Creek Provincial Park (Greenlee 1983) provided detailed information which can be extrapolated to at least a portion of potential Sites 1 and 4. Medium textured glacial till parent material dominate in the uplands, with medium to very coarse textured fluvial sediments occurring along the Willow Creek floodplain (Greenlee 1983). Key soil subgroups found by Greenlee included Calcareous Dark Brown Chernozems, Orthic Dark Brown Chernozems, Rego Dark Brown Chernozems, Orthic Regosols, Gleyed Regosols, Rego Gleysols, Rego Gleysols saline phase, and a Gleyed Solonetz. The reader is referred to Greenlee (1983) for excellent taxonomic, chemical and physical descriptions for each of these subgroups. Generally the Chernozems occur in the upland moraine (till of varying texture), along slopes on colluvium and in the creek floodplain on medium to moderately-fine textured fluvial sediments. The Regosols are found on medium to coarse textured fluvial sediments along the creek floodplain, and on steep valley slopes.

Soils of the Pine Coulee area are expected to be most similar to those of the Willow Creek site, with the exception of the coulee floor. Upland soils are are most likely Dark Brown Chernozems with inclusions of saline Regosols in depressions and temporary sloughs found scattered throughout. Steep to moderately sloping coulee walls should be dominated by Chernozems, with Regosols more likely on the steepest slopes. The presence of salts is obvious, scattered throughout the length of the Pine Coulee glacio-fluvial floodplain. Soils of the coulee floor are likely of the Regosolic (saline phase), Chernozemic or Solonetzic orders.

6.3.1.3 Stability and Reclamation Considerations

Erosion and/or reclamation problems area not anticipated to be great at Site 1. For this site, an estimated 85.8 ha of valley slopes exceed 30^{o}, with only 32 ha of this area demonstrating erosion (i.e., bare soil or rock). Of the 85.8 ha, an estimated 44.5 ha occur on drier south to west aspects, 29.2 ha occur on cooler north to east aspects, and 12.1 ha have steep slopes with variable aspect. Saline soils appear limited to depressional areas in the uplands, with a total of eleven small saline sloughs (occupying as estimated 32 ha) located in the vicinity of the potential dam site. These localized areas could present some reclamation problems, if disturbed by dam development.

The Pine Coulee site has the least potential for erosion problems..Although steep slopes ($>30^{o}$) occur on an estimated 169.9 ha of valley sides, only 3.3 ha appear eroded (i.e., bare soil or rock). Dry south to west aspect slopes comprise 80.2 ha, more mesic north to east aspects comprise 59.0 ha, and the remaining 30.7 ha of the steeply sloped areas have variable aspect. Two saline sloughs occur in the upland area adjacent to the potential dam site (12 ha) and proposed saddle dyke (5 ha). If disturbed by project development, these could present localized reclamation problems.

Site 3 possesses the greatest total area of steep ($>30^{o}$) slopes of the four sites. The drier (south to west aspect) steep slopes occupy 189.1 ha, while 26.1 ha are north to east facing and 84.7 ha are classified as variable aspect. Thirty-two hectares of these steep slopes appear eroded, with bare soil or rock present. From a topographic perspective, this site has the greatest potential for surficial erosion. However, no indication of mass wastage potential is evident.

There are only two known small saline sloughs (totalling about 2 ha) in the vicinity of Site 3 which may constitute reclamation problems, if disturbed. Project-related erosion on dry, steep slopes with shallow soils would present the greatest reclamation challenge.

The soil/slope erodibility and reclamation considerations for Site 4 are similar to those of Site 2, with few additional considerations occurring for the Willow Creek Valley area. A total of 345.7 ha of the site are steep slopes (> 30 degrees), of which 115.7 ha are drier south to west aspect, 73.9 ha are north to east facing and 156.1 ha have variable aspect. There are only 20.1 ha of eroded slopes mapped. There are no saline sloughs in the immediate potential dam site vicinity, so no soil chemistry limitations to reclamation are expected.

A soil sampling program would be required at the four reservoir sites to ascertain specific soil types, their related susceptibility to erosion, and management in reclamation.

6.3.2 Land Use

Land use of the Willow Creek study area is primarily agricultural and is limited to small grain crops, hayland, and use of seeded pasture and native range for cattle grazing. Table 6.1 summarizes land use in the four potential reservoir sites.

Land use of the Willow Creek site (Site 1) is predominately agricultural. Of the twenty-nine quarter sections of land included in the site,, only five quarter sections are crown land. The predominant land use (950.6 ha) is domestic grazing of forest land, shrubland, seeded pasture and native range. Cropland is the predominant land use

Table 6.1 Land use at the four potential reservoir sites.

Reservoir Site	Land Use	Total Area (ha) for each Land Use By Topographic Position			Totals
		Valley Bottom	Slopes	Uplands	
1. Willow Creek	Forest Grazing/ Recreation	102.0	1.9	0	103.9
	Grazing				
	- shrubland	37.0	33.9	11.1	82.0
	- seeded pasture	77.2	0	380.1	457.3
	- native grassland	60.1	149.3	98.0	307.4
	Cropland	0	0	740.5	740.5
	Other*	56.8	42.8	119.1	218.7
	Total	333.1	227.9	1348.8	1909.8
2. Pine Coulee	Forest Grazing/ Recreation	0	12.9	1.2	14.1
	Grazing				
	- shrubland	128.5	93.4	15.7	237.6
	- seeded pasture	71.1	172.8	614.0	857.9
	- native grassland	81.0	307.4	229.7	618.1
	Cropland	0	31.1	842.5	873.6
	Other	7.6	7.2	88.8	103.6
	Total	288.2	624.8	1791.9	2704.9
3. Kuntz Creek/ Willow Creek	Forest Grazing/ Recreation	33.5	194.5	32.1	260.1
	Grazing				
	- shrubland	53.9	160.4	248.4	462.7
	- seeded pasture	33.5	82.6	17.1	133.2
	- native grassland	0	252.1	594.3	846.4
	Cropland	70.3	13.5	11.1	94.9
	Other	13.7	14.4	0	28.1
	Total	204.9	717.5	903.0	1825.4
4. Pine Coulee/ Willow Creek	Forest Grazing/ Recreation	51.4	13.6	1.2	66.2
	Grazing				
	- shrubland	197.0	116.6	17.9	331.5
	- seeded pasture	152.1	234.4	847.8	1234.3
	- native grassland	81.0	495.0	404.7	980.7
	Cropland	13.3	31.1	842.5	886.9
	Other	12.2	24.9	92.4	129.5
	Total	507.0	915.6	2206.5	3629.1

* Other category includes land cover types such as bare soil, open water, gravel pits, wetlands, etc.

on the upland glacial moraine (740.5 ha). The active floodplain commonly possesses poplar and shrub plant communities which provide better wildlife habitat. Sections (77.2 ha) of the floodplain were previously seeded and are grazed by cattle. An apiary is also present on the floodplain.

The Pine Coulee site (Site 2) is predominantly old seeded pasture. On the steeper coulee slopes, the seeded pasture is interspersed with native range. An estimated 47, 1/4 sections are included in this study site, only two of which are crown land. The dominant land use at the site is domestic livestock grazing of native grassland (618.1 ha) and seeded pasture (857.9 ha). Grazing use of deciduous forests (14.1 ha) and shrubland (237.6 ha) is less common. Cropland is predominant (842.5 ha) in the upland areas, and covers a total of 8731.6 ha for the entire study site. Other land cover types (103.6 ha) include wetlands and rock/bare soil. Very little wildlife habitat exists in the form of tall shrub or tree cover at this site. A ranch house and its associated structures would be flooded by this proposed reservoir.

The Kuntz Creek/Willow Creek site (Site 3) has the steepest terrain of the three areas. It is predominantly forested (260.1 ha), native range (846.4 ha), shrubland (462.7 ha) and seeded pasture (133.2 ha), with smaller total areas of cropland (94.9 ha) also occurring. The variety and interspersal of forest, shrub and herbaceous plant communities with the rolling topography indicates very good wildlife habitat in this area. One ranch house and its buildings are located in the Willow Creek floodplain in this study site.

The Pine Coulee/Willow Creek site (Site 4) combines the Pine Coulee site (Site 2) and a portion of the Willow Creek floodplain upstream from Site 1. As such, it represents a combination of the primarily grassed Pine Coulee with the predominant riparian deciduous forest and shrubland present in the Willow Creek valley. It also encompasses the Willow Creek Provincial Park. Camping, hiking and fishing are some of the park-related recreation activities. Table 6.2 summarizes the overnight camping use of the Provincial Park for the past eight years. Table 6.3 further details the overnight and day use for the past five years (Alberta Recreation and Parks 1984). The data indicate an average overnight use of 3,837 camping party nights over the past five years, and a five year average day use of 21,991 day user days. Both types of use fluctuated greatly over the five year period, with no apparent trend toward increased or declining park use. This site would also flood the same ranch structures discussed for Site 2.

Land use in the northern portion of this site is typified by domestic grazing of seeded pasture and native range within the Coulee and along its slopes, and small grain crop production in the uplands. Land use along Willow Creek is restricted to domestic grazing of the shrubland and seeded pasture in the valley bottom, and recreational use in and around the Provincial Park for camping, picnicking, hiking and fishing. Cropland again dominates the upland areas. Site 4 includes portions of 49 privately owned 1/4 sections within the one kilometre study boundary. An additional seven 1/4 sections are crown land. Considering the entire study site, 66.2 ha are forested and possibly used for either grazing, recreation or wildlife habitat, shrubland occupies an estimated 33.15 ha with similar uses, grazing of seeded pasture or native range is the land use on an estimated 2215 ha, and small grain and hay production occupies an estimated 886.9 ha.

6.3.2.1 Land Use Implications From Flooding. Flooding as a result of dam site construction would predominately affect private lands at all four potential reservoir sites. Valley bottoms would be the primary lands affected, with contributing coulees and drainages also possibly affected - the level of inundation would be determined by the final engineering design at each site. A breakdown by land use for all valley bottom areas is given in Table 6.1.

Crown land affected by flooding in the Willow Creek Site (1) is limited to portions of E 1/2, NW 1/4-13-28-W4 and SE 1/4 22-13-28-W4.

Table 6.2. Overnight recreational use of Willow Creek Provincial Park.

WILLOW CREEK PROVINCIAL PARK	1977	1978	1979	1980	1981	1982	1983	1984	Eight Year Average
Capacity	50	50	50	50	50	50	50	50	50
Permits Sold	4,525	2,500	2,300	2,375	2,275	2,150	2,425	1,925	2,559
Camping Party Nights	4,525	4,006	4,056	3,766	3,864	3,924	4,372	3,259	3,972
Individual Camper Nights	17,126	14,128	14,426	12,586	12,962	13,378	14,339	11,438	13,798
Average Party Size	3.8	3.5	3.6	3.3	3.4	3.4	3.3	3.5	3.5
Average Stay/Permit (Days)	1.0	1.6	1.8	1.6	1.7	1.8	1.8	1.7	1.6

Source: Alberta Recreation and Parks 1984.

Table 6.3 Detailed recreational use of Willow Creek Provincial Park 1980-1984 (Park capacity is 150 stalls).

	PARK ATTENDANCE STATISTICS							DAY USE STATISTICS			
	NO. OF VEHICLES BY YEAR BY TYPE							NUMBER OF DAY USER DAYS BY YEAR			
YEAR	TOTAL	NON-REC. WEEKDAY	NON-REC. WEEKEND	CAMPING WEEKDAY	CAMPING WEEKEND	DAY USE WEEKDAY	DAY USE WEEKEND	TOTAL	WEEKDAY	WEEKEND	AVG. DAY USE PARTY SIZE
1980	13,599	305	178	860	1,529	7,169	3,558	41,012	27,421	13,591	3.82
1981	6,810	269	149	1,290	2,572	1,487	1,043	9,752	5,744	4,008	3.85
1982	5,389	154	58	902	1,978	1,116	1,181	6,891	3,348	3,543	3.00
1983	15,902	743	264	1,638	2,551	6,393	4,313	36,203	21,450	14,753	3.38
1984	8,431	-	-	1,188	2,046	2,167	3,030	16,096	7,091	9,005	3.18
AVERAGE	10,026	368	162	1,176	2,135	3,666	2,625	21,991	13,011	8,980	3.45

CAMPGROUND STATISTICS

	CAMPING PARTY NIGHTS			NUMBER OF NIGHTS AT PERCENTAGE CAPACITY								AVERAGE DAILY OCCUPANCY		INDIVIDUAL CAMPER NIGHTS	
YEAR	TOTAL	WEEKDAY	WEEKEND	100+	100	90-99	75-89	50-74	25-49	10-24	0-9	WEEKDAY %	WEEKEND %	INDIV. NIGHTS	AVERAGE PARTY SIZE
1980	3,766	1,194	2,572		1		3	14	14	40	52	9	43	12,586	3.34
1981	3,864	1,291	2,573	31			5	27	21	8	32	30	131	12,962	3.35
1982	3,924	1,280	2,644	26	2	2	4	24	22	15	29	30	135	13,378	3.40
1983	4,372	1,634	2,738	32		2	5	25	24	14	22	37	148	14,339	3.27
1984	3,259	1,218	2,041	25	2	1	7	18	24	13	34	29	102	11,438	3.50
AVERAGE	3,837	1,323	2,514	23	1	1	5	22	21	18	34	27	112	12,941	3.37

Source: Alberta Recreation and Parks 1984.

The total valley bottom area (private and crown land) potentially inundated is estimated at 333.1 ha, with an additional 107.9 ha of contributing drainages and coulees possibly affected.

The Pine Coulee Site (2) crown land is limited to one quarter section (SW 1/4 34-13-28-W4) at the dam site. The valley bottom totals an estimated 288.2 ha with an additional 177.5 ha of contributing coulees possibly affected.

Site 3 (Kuntz Creek/Willow Creek) crown land that would be affected by flooding occurs in SE 1/4 2-14-30-W4 and NE 1/4 and SW 1/4, S 1/2 2-14-1-W5. A total of 204.9 ha occurs in the valley bottom, 102.0 ha is terraced land adjacent to the valley bottom, and 427.7 ha of contributing drainages and coulees might be inundated.

Crown land occurs in SW 1/4 34, N 1/2 28, SE 1/4 33, NE 1/4 29 and SE 1/4 321-13-28-W4 in the Pine Coulee/Willow Creek Site (4). Inundation would affect on estimated 218.8 ha of the Willow Creek valley bottom and 288.2 ha of Pine Coulee valley bottom under this scenario. There is an additional 368.7 ha of contributing coulees that might be affected by the dam construction.

Thus, Site 4 would affect the greatest total land area, with 507.0 ha valley bottom area potentially flooded. Site 1 would affect the next largest total area (333.1 ha) followed by Site 2 (288.2 ha) and finally Site 3 (204.9 ha).

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7.0 HISTORIC RESOURCES

7.1 COMPONENT REQUIREMENTS

As specified in the Terms of Reference, the objectives of the historical resources study were to:

1. identify all previously recorded historic, prehistoric, and palaeontological resources in or near the four reservoir sites,
2. provide a brief evaluation of the significance of the sites,
3. discuss the probability of finding additional historical resource sites at each of the potential reservoir locations,
4. rank the historical resource potential of the four sites, and
5. develop recommendations regarding the nature and level of effort required to conduct impact assessments specific to each site.

7.2 TERMINOLOGY

Prehistoric, historic, and palaeontological sites are defined as historical resources by the Alberta Historical Resources Act (1980). Prehistoric sites are comprised of artifacts, features, and residues of native origin. They predate the arrival of Europeans and are typically characterized by modified bone, stone and stone structures. Historic sites are characterized by structures, features, and objects of European influence. Buildings and building remains represent the most prominent type of historic site. Palaeontological sites are areas where fossils of animals or plants have been preserved. Palaeontological sites include only those sites which contain fossils of multicellular invertebrates, vertebrates, and plants.

7.3 POTENTIAL ADVERSE IMPACTS

Historical resources are non-renewable. They occur both on and below the surface of the ground and submerged under water and may be altered, damaged or destroyed by development projects which modify the landscape. Proposed development of one of the four identified potential reservoirs in the Willow Creek Drainage Basin could adversely affect these sites through a variety of actions during both the construction and operation phases.

7.4 DIMENSIONS OF IMPACT

Three dimensions of impact have been identified which are relevant to the effects of development on historical resources: 1) scale of impact, 2) nature of impact, and 3) degree of impact (Figure 7-1) (Fedirchuk McCullough & Associates Ltd. 1983).

7.4.1 Scale of Impact

Impacts can occur on three levels of historical resource phenomena (Lenihan 1981): regional, local, and site. Regional data include the historical resources within the region and the environmental context within which the sites occur. Local data consist of individual sites or site clusters, the information contained within the sites as it pertains to stratigraphic and spatial relationships within the context of the regional data. Site data consist of the individual items or remains occurring at the individual sites.

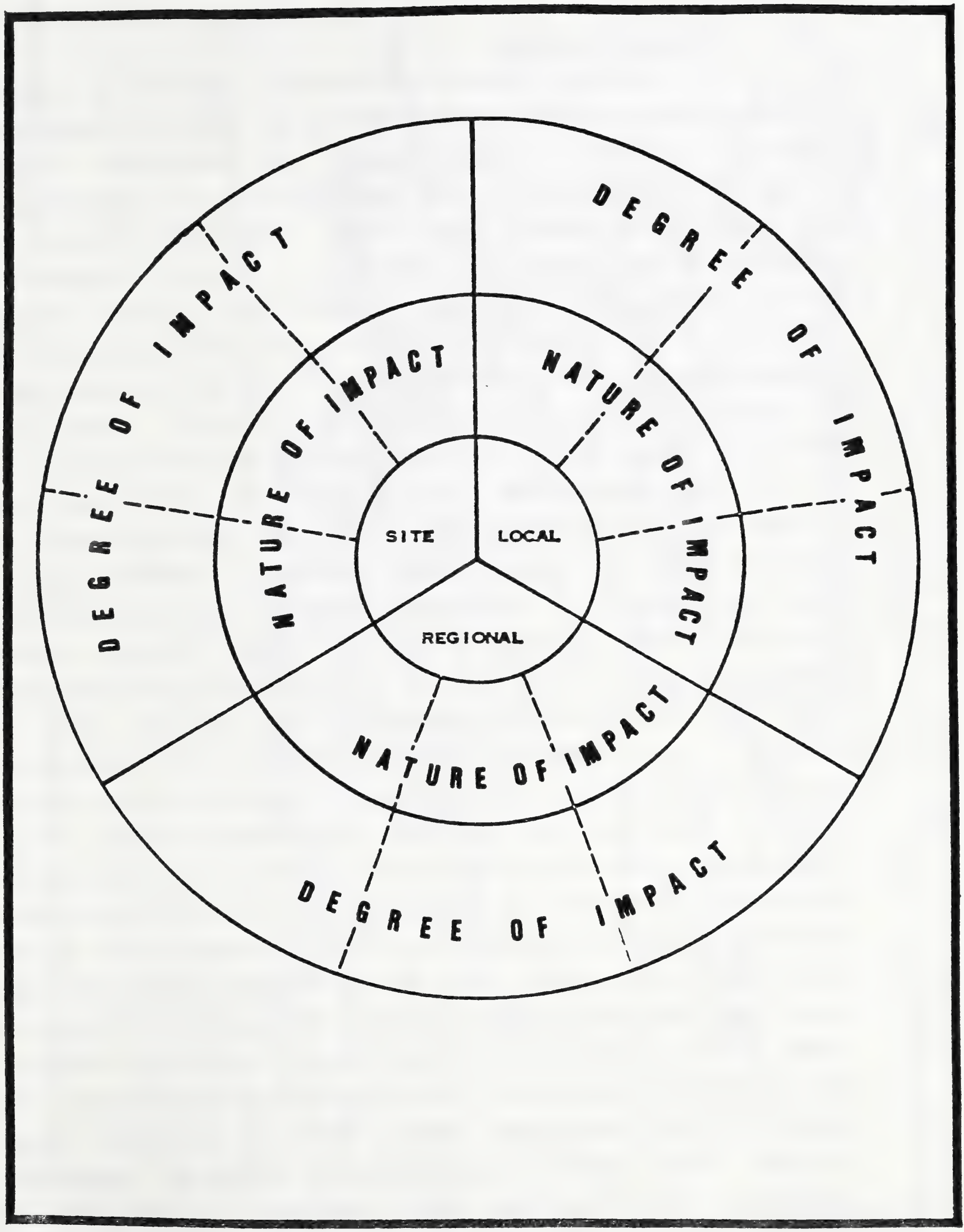


Figure 7-1 SCHEMATIZATION OF POTENTIAL IMPACTS ON HISTORICAL RESOURCE DATA

7.4.2 Nature of Impacts

The potential impacts on historical resources by proposed projects involving ground disturbance may be primary, secondary or tertiary in nature. Primary Impacts are predictable, planned construction disturbance factors necessitated by the objectives of the project. The primary impact zones include the site and the locations of the ancilliary facilities. Potential construction impacts within these zones may include land clearing, gradin excavation, soil stripping, landfill, and bank stabilizatio Secondary Impacts are adverse effects on historical resources whic are produced by operationalization of the facility. Three impac zones are recognized: 1) permanent conservation pool zone, 2) shoreline fluctuation zone, and 3) downstream zone (Figure 7-2). The permanent conservation pool zone consists of the reservoir below the average annual drawdown. Inundation of this zone would result in subsurface erosion, and slumping, soil saturation, and biochemical action. Other impacts include inundation, erosion, or siltation of sites within the permanent flood zone and biochemical degradation of the site soils and contexts. The shoreline fluctuation zone consists of that portion of the reservoir between the permanent conservation pool zone and the upper flood pool zone. Of major concern are potential effects on historical resources located on the perimeters of the reservoir because this zone would be subject to most intensive and extensive mechanical erosion. Secondary erosional processes such as wind erosion and water runoff could be intensified during low water levels when the newly created surfaces are exposed. This zone is highly subject to effects of variable moisture conditions, freezing, and thawing. The magnitude of shoreline erosion would depend on the degree of slope, groundwater seepage, shoreline elevations, length of fetch, local material properties, and degree of vegetational protection. The downstream zone, consisting of the landscape downstream from the dam, could be altered as a result of altered

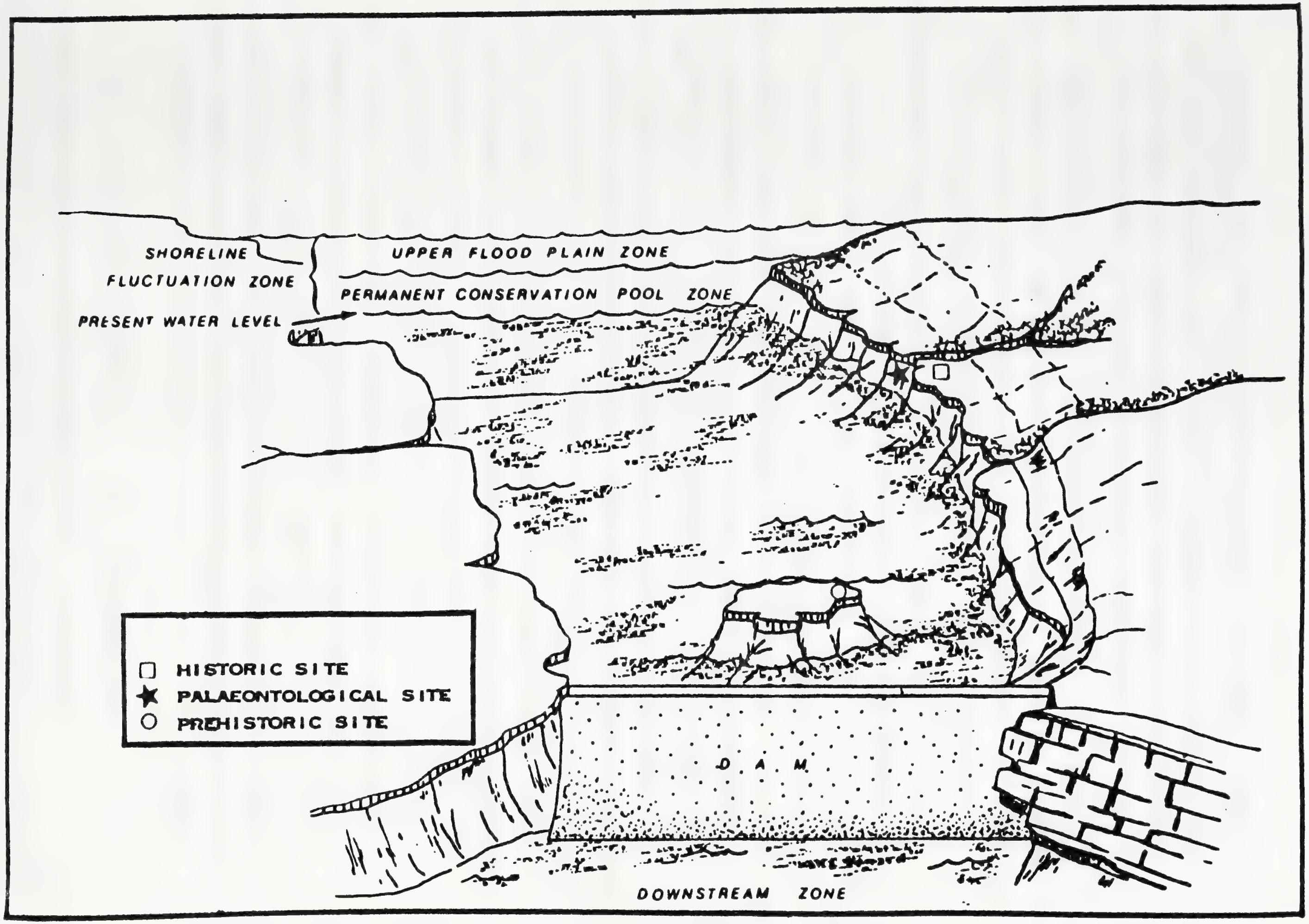


Figure 7-2 SECONDARY IMPACT ZONES (After H.S.A. Historical Studies Associates Inc. 1984)

water flows affecting rates of erosion. Tertiary Impacts are not directly related to construction of the development facility. They are likely to occur in the backshore zone. They are the result of project induced changes in demography and land use. Secondary disturbance factors resulting from a higher intensity of land use both upstream and downstream within the region could adversely affect historical resource sites. Long term impacts from recreational activity in the shoreline fluctuation zone may also occur through the removal of artifacts and palaeontological specimens and disruption of exposed sites.

7.4.3 Degree of Impact

Degree of impact to historical resources is reflected in the magnitude of disturbance or loss which could occur at each level of data and is the result of the nature of the impact. The degree of impact may be major, moderate or minor. Major Impact is defined as the loss of a significant proportion of data at either the site, local or regional level. With major impact, the interpretive capacity of the remains following impact is minimal. Moderate Impact is defined as the loss of a proportion of the data at either the site, local or regional level with a significant proportion of the data remaining unimpaired. After moderate impact, the interpretive capacity of the remains is hindered by the loss of basic data about the past. Minor Impact is defined as the loss of a minor proportion of data at either the site, local or regional level. After minor impact, the interpretive capacity of the remains is virtually intact, limited only by the loss of minor items and features.

7.5 METHODOLOGY

Initially, a literature review was conducted to place the study area into perspective relative to the regional prehistory, history, and palaeontology. An inventory of known historical resources and their characteristics, including archaeological, historical, and palaeontological remains in the potential four reservoirs sites, was compiled from the site files available at the Archaeological Survey of Alberta and Historic Sites Service. The area of the site file search included an one-mile buffer zone surrounding the potential reservoir areas. Maps of 1:50,000 scale of each of the reservoir areas were used to plot the locations of the previously recorded sites.

The remainder of the study involved analysis of the available data base with the objective of identifying prehistoric human use patterns, significant historic themes and sub-themes, and determining the palaeontological significance of the area and of identifying major data gaps which must be addressed in the completion of an Historical Resources Impact Assessment. Based on the data available, prehistoric site types were evaluated as to their potential significance. Historical data on the area were used to identify historic themes and sub-themes which best reflect the role that the study area played in the historical development of southwestern Alberta. Palaeontological data were analyzed to provide a basis for determining the relative significance of the study area in terms of the regional geology. All of the information on each of the three aspects of historical resources was used to assess the relative potential of the four sites for as yet unrecorded sites and to provide recommendations as to the nature of the historical resources impact assessment required to inventory and adequately assess the historical resources to be impacted by construction of a reservoir.

7.6 RESOURCE OVERVIEW

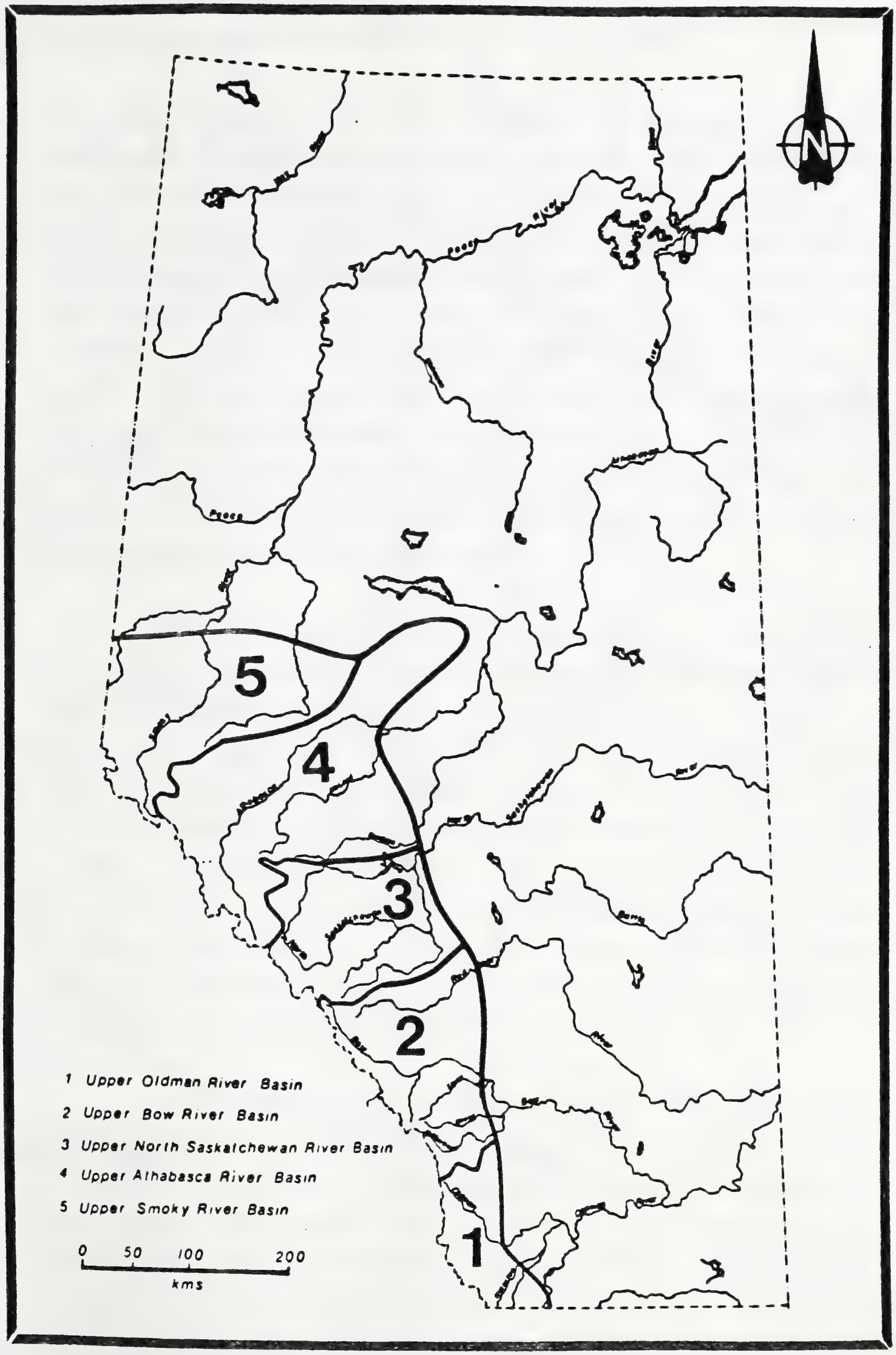
7.6.1 Prehistoric Resources

The study area is situated in the Eastern Slopes cultural area. This region is naturally sectioned along its north-south axis by upper river drainage basins which are separated from lower drainage basins by the eastern margin of the Foothills Belt. In Alberta, six archaeological regions based on major upper drainage basins along the Eastern Slopes have been identified: the Oldman, Bow, Red Deer, North Saskatchewan, Athabasca, and Smoky River basins (McCullough and Fedirchuk 1983) (Figure 7-3). The study area is situated in the upper Oldman River basin.

The upper Oldman River basin is situated within the ice-free corridor, a narrow tract of land between the Laurentide and Cordilleran glaciers which covered much of North America during the Wisconsin Period (ca. 70000 - 10000 B.C.). The ice-free corridor, extending along the eastern slopes of the Rocky Mountains northward from approximately the 49th Parallel to the interior Yukon and Arctic Coast, is viewed as being an early prehistoric migration route into the New World.

The Laurentide and Cordilleran glaciers may have coalesced during the Early Wisconsin (120000 to 50000 years B.P.), closing the corridor. Current evidence indicates that the corridor was likely completely open during the Middle Wisconsin (50000 - 25000 years B.P.) and open from the 49th Parallel to the Jasper-Edmonton area during the Late Wisconsin (25000 - 10000 years B.P.), closing for a maximum of 10,000 years in the area from Jasper-Edmonton northward to the British Columbia-Alberta border and open beyond to the Arctic Ocean (Rutter 1980). In the study area, it appears that the ice free corridor included the mouths and the major valley systems of the eastern Cordilleran mountain front of southern Alberta (Rutter 1984).

Historically, the Eastern Slopes were utilized for bison hunting by the Piegan from the plains and the Kutenai from the plateau (Figure 7-4). It is clear from early historic literature


N
5
4
3
2
1
1 Upper Oldman River Basin
2 Upper Bow River Basin
3 Upper North Saskatchewan River Basin
4 Upper Athabasca River Basin
5 Upper Smoky River Basin
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50
100
200
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Figure 7-3 MAJOR UPPER DRAINAGE BASINS ALONG THE EASTERN SLOPES

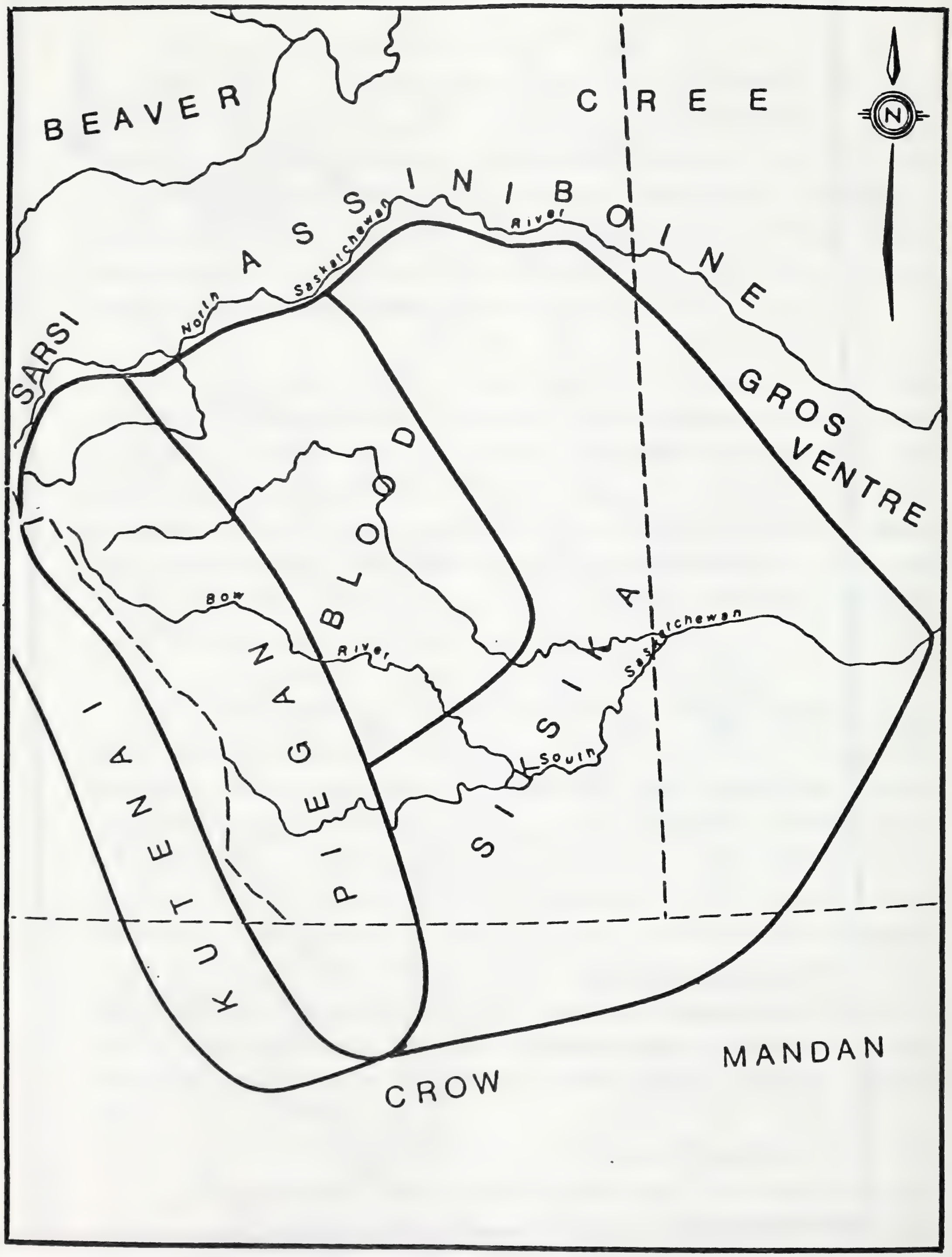


Figure 7-4 DISTRIBUTION OF ABORIGINAL GROUPS IN SOUTHERN ALBERTA IN THE LATE EIGHTEENTH CENTURY

that the Piegan were instrumental in forcing the original inhabitants, probably the Kutenai, Flathead, and Shoshone, out of their previous territory along the Eastern Slopes to occupy lands within the mountain ranges. Archaeological studies conducted within the plains/montane contact area demonstrate that the study area was continuously occupied over the last 12,000 years (see Christensen 1971; Lifeways of Canada Limited 1974; McIntyre and Reeves 1975; Reeves 1976; McCullough 1979; Damp et al. 1980; Gryba and Barnett 1981; Fedje 1983; McCullough and Fedirchuk 1983). The reconstructed cultural history indicates that bison represented the major focus of economic activities along the plains/montane contact, which was the wintering habitat of the plains bison.

The distribution of the previously recorded prehistoric sites within the Eastern Slopes archaeological region indicates that there is a strong association of sites with lake, river, and creek margins. Although this distribution pattern partially reflects the focus of research investigations in these areas, it also reflects the environmental restrictions placed upon human populations. Terrain influenced many forms of human activity, directing travel, biasing routes of communication, and restricting occupation areas to selected localities. As a result, human populations were not uniformly distributed across the landscape, but were non-randomly clustered within the most suitable habitats.

During prehistoric times, the region may have been jointly used by plains and plateau cultural groups either simultaneously or during alternate seasons. Alternatively, the region may have served as a buffer zone between the plains and the plateau and utilized inconsistently and intermittently by both plains and plateau native groups. It is also possible that in prehistoric times the region may have been used exclusively by cultural groups specifically adapted to the Eastern Slopes environment.

7.6.2 Historic Resources

Early exploration and settlement within the present boundaries of Alberta was the result of the search for new fur sources and for this reason tended to concentrate in the northern forested regions in proximity to the major water routes within the Churchill and Mackenzie Drainage systems. There was little interest in southern Alberta prior to 1857 when Captain John Palliser was commissioned by the British Government to investigate the suitability of the Plains region of western Canada for agricultural development. Palliser and his associates, notably Dr. James Hector and Thomas Blakiston travelled extensively within the study region, and recorded their observations. Palliser, in his report dismissed the arid southern grassland portions of the province (the "Palliser Triangle") as having little or no potential for agricultural purposes.

In 1869, the territories controlled by the Hudson's Bay Company were surrendered to the British Crown and then in 1870, following the Red River Rebellion, were transferred to the Dominion of Canada. With the transfer of these lands, the Canadian Government was faced with the task of settling the vast area between the Great Lakes and the Pacific Ocean. As a result, measures dealing with the Indians, the survey of land, the development of a transportation system, the establishment of a law enforcement body, and the encouragement and control of immigration were implemented.

In the late 1860's and early 1870's, with the development of steamship facilities in the United States which made profitable the transport of the heavy furs/hides from the plains, there was a growing demand for buffalo robes and buffalo leather for machinery belts in the East (Fooks 1983). Since the use of liquor as a trading medium with the Plains Indians was illegal in the United States and was for the first time being actively enforced, traders from Fort Benton in Montana seized the opportunity to set up posts across the Canadian border and capitalize on the plentiful supply of buffalo hides which the various Plains tribes would provide in exchange for cheap whiskey ("Montana red-eye") with no threat of interference from Canadian authorities.

The movement of traders into Canadian territory may have followed the "Old North Trail" (Fooks 1983), an ancient trail used by the Plains Indians in moving north to the barren lands and south to Mexico (McClintock 1968). In 1869, J. J. Healy and A. B. Hamilton built Fort Hamilton at the junction of the Oldman and St. Mary's rivers, near the present city of Lethbridge (Fooks 1983). Although the original Fort Hamilton likely operated only one season before it was destroyed by fire, word of Hamilton and Healy's success spread rapidly and served to attract other whiskey traders to southern Alberta. Fort Hamilton was rebuilt in 1870 and came to be known as Fort Whoop-Up. It was one of the most notorious whiskey posts in the Northwest Territories and the trail leading from Fort Benton to Whoop-Up was known as the Whoop-Up Trail. Numerous other whiskey "posts" were established along the trail leading to and from Whoop-up, including such facilities as Standoff, Slideout, Conrad's Post, Milk River Ridge, Fort Spitzie, Kipp's Post, and Fred Kanouse's Fort Warren.

A buffalo hunter and whiskey trader by the name of Henry Kountz (Kuntz) is reported to be the first permanent resident in the Willow Creek area. He arrived in 1870 and established himself at the location which came to be known as the Leavings (Claresholm History Book Club 1974). Another whiskey post, operated by William Bond, Harry "Kamoose" Taylor and others, was located in Pine Coulee (Turner 1950a).

The bloodshed and violence resulting from the whiskey trade combined with the threat of an American takeover of the largely uninhabited western plains and Indian wars precipitated by massacres occurring in the United States were instrumental in the Dominion government's passage of the North West Mounted Police Act in 1873. A force of three hundred men was promptly recruited for a three year term and preparations made for an arduous trek west. In 1874, the small police force, charged with maintaining law and order in the Northwest Territories, arrived in southern Alberta. The mere presence of the North West Mounted Police resulted in the suppression of the most violent aspects of the liquor trade. As a result most of the whiskey posts were either abandoned or commenced legitimate operation.

In Alberta the force was initially established at the confluence of the Oldman River and Willow Creek in late 1874. The post was called Fort Macleod and because it was centrally located and accessible it immediately became a nucleus of settlement. In 1875 two other North West Mounted Police posts were established, Fort Calgary at the junction of the Bow and Elbow rivers and Fort Walsh in the Cypress Hills. Fort Macleod was the centre for police activity and the security afforded by the police in turn led to a gradual influx of settlers and prospective ranchers into southern Alberta, most coming from the United States (Turner 1950a). Prior to the arrival of the Canadian Pacific Railway in Calgary in 1883, Fort Benton was the supply centre for southern Alberta and all goods were freighted by "bull teams" up to Fort Macleod and Fort Calgary on the Benton Trail (Figure 7-5).

In 1880 as a means of encouraging settlement in the western plains, the federal government instituted a land lease system whereby large tracts of grazing land were turned over to ranchers at a very nominal rate provided the lands were stocked within a

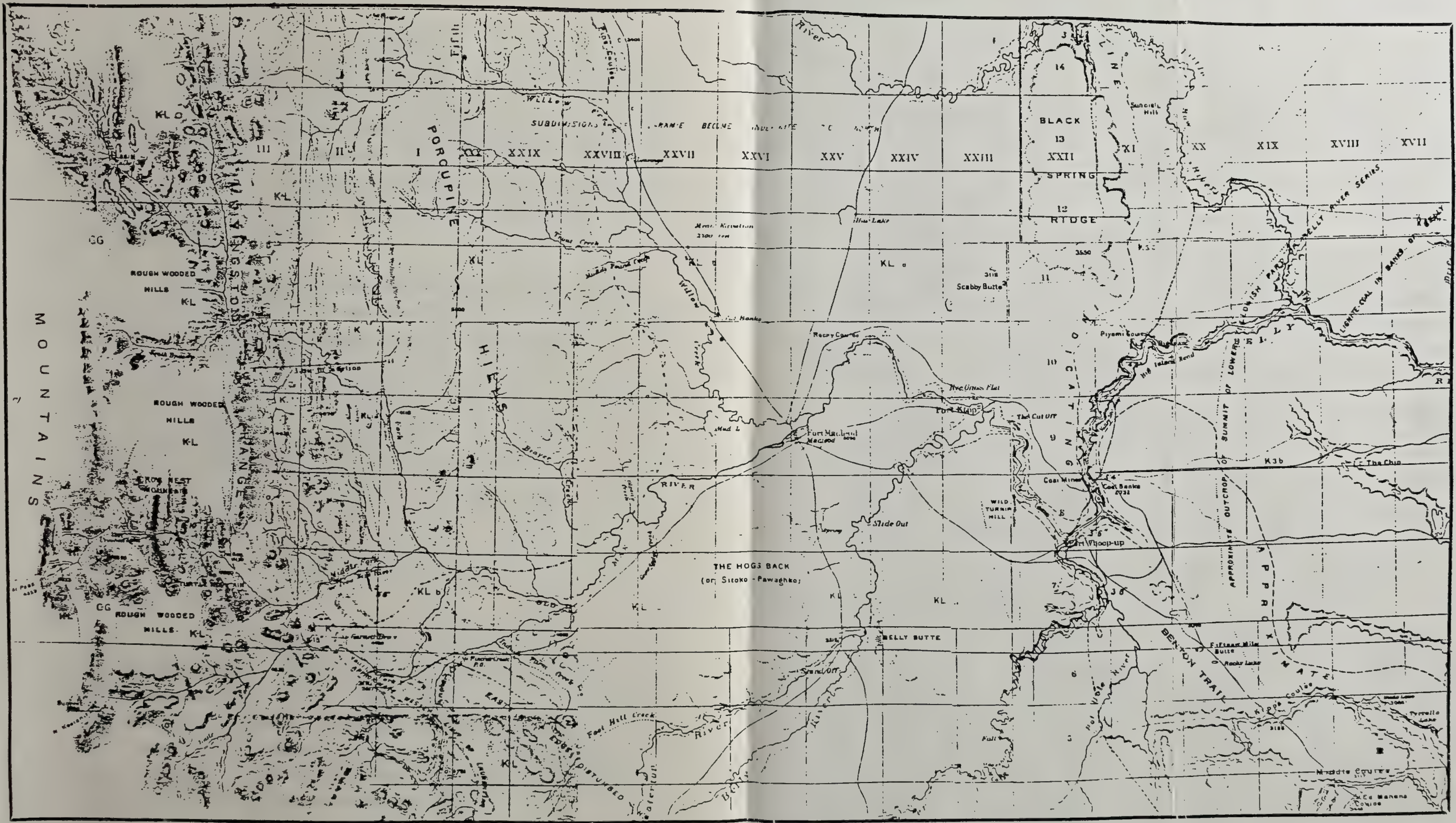


Figure 7-5 PORTION OF MAP OF BOW AND BELLY RIVERS BY G. M. DAWSON (1884) DEPICTING EARLY TRAILS

three year period. This system served as an incentive to cattlemen already familiar with the region and encouraged wealthy Eastern, British and American interests to form large scale syndicates. One of the largest of these ranches was the Oxley Ranch which was incorporated in London in 1882 by Alexander Staveley Hill and his wife, the Earl and Countess of Lathom, Mr. and Mrs. George Baird, and Colonel Villiers. John Roderick Craig from Ontario was resident manager of the ranch.

The Oxley Ranch secured two 100,000 acre grazing leases, one in the Porcupine Hills and one near the mouth of the Little Bow River (Craig 1971). Henry Kountz's (Kuntz) cabin/stopping house on the Leavings of Willow Creek was purchased by the company and served as the first headquarters. ["Leavings is a name commonly used when the trail leaves the river" (Craig 1971:29)]. In 1884 or 1885 the Oxley Ranch headquarters were moved about six miles up Willow Creek. In 1884, the North West Mounted Police established a detachment at the Leavings, renting a log cabin from the Oxley Ranch. A large sandstone barn set into a hillside was part of the detachment's facilities. Approximately three quarter miles south of the police detachment a stagecoach relay station was also completed (Claresholm Historical Book Club 1974).

By 1884, cattle ranching was a well established industry in southern Alberta and included many North West Mounted Police who having completed their terms of duty started ranching in familiar territories (e.g. Winder Ranch). With increased settlement the early ranchers, particularly those who had the larger operations, began to sell to smaller concerns. Ranching has retained an important role in the area to the present day.

7.6.3 Palaeontological Resources

7.6.3.1 Introduction. To date, only one geological study has been conducted specifically within one of the four potential reservoir areas. Carrigy (1971) conducted a bedrock study of the sandstones in the Kuntz Creek. Based on the studies conducted in the general area by Carrigy (1971), Douglas (1950), and Irish (1968, 1971), the four potential reservoir locations are underlain by strata of the Porcupine Hills Formation. Site No. 1, Willow Creek near Claresholm, Site No. 2, Pine Coulee, and Site No. 4, Pine Coulee/Willow Creek, would be constructed on strata low in the Porcupine Hills Formation on the east side of the Alberta Syncline, whereas Site No. 3, Willow Creek near Lane/Kuntz Creek would be constructed on strata close to the middle of the formation and would straddle the axis of the Alberta Syncline.

The Porcupine Hills Formation was named by Dawson (1883) after the type locality, the Porcupine Hills of southwestern Alberta. The formation unconformably (?) overlies the Willow Creek Formation (Douglas 1950) along the west side of the Porcupine Hills and gradationally overlies this formation to the east of the hills (Tozer 1956). It ranges up to 1000 metres in thickness.

7.6.3.2 Stratigraphy and lithology. Lithologically, the Porcupine Hills Formation consists of medium- to coarse-grained cross stratified sandstone, interbedded light to dark grey shales, silty shales, and siltstones. Conglomerates of limestone are locally present near the base of the formation. Locally, gastropod coquinas are present. Individual sandstone units range from less than one metre to fifteen metres or more in thickness and are distinctly lenticular in cross section. Sedimentary structures and lithological sequences indicate that the sandstones were deposited as fluvial channel deposits whereas the siltstones and shales represent overbank deposition in levees and lacustrine environments.

The geographic distribution of the formation has been variously interpreted. Dawson (1883) assigned strata extending from the south end of the Porcupine Hills to the Calgary area to the Porcupine Hills Formation. Tozer (1956), on the other hand, arbitrarily assigned strata south of Township 13 to the Porcupine Hills Formation and those to the north of that township to the Paskapoo Formation. Carrigy (1971), based on lithological, sedimentological, and petrological data, mapped the formation as far north as the Red Deer River. Carrigy's extension of the distribution of this formation indicates that it overlapped the Paskapoo Formation north of Calgary. Although the latter interpretation is being reconsidered, it does have considerable implications to the floral and faunal content of the formation.

7.6.3.3 Palaeontology. Because of the confusion in terminology regarding the often arbitrary assignment of strata to either the Porcupine Hills Formation or the Paskapoo Formation, fossils occurring in both formations are discussed. All fossils could be expected to occur within the Porcupine Hills Formation, especially in complete sections along the eastern side of the Porcupine Hills.

Fossil Plants

Bell (1949) and Berry (1926) reported fossil plants from the Porcupine Hills (?) or Willow Creek Formation and the Paskapoo Formation (Table 7-1). Charophytes (fresh water algae) have been recovered from the Willow Creek and Porcupine Hills formations by Germundson (1965).

Reptiles

Turtles - Russell (1930a) recorded a new species of turtle (*Aspiderites superstes* Russell) from the Paskapoo Formation on the Highwood River just below the mouth of the Sheep River (LSD11.32.20.28.W4M). These strata are currently assigned to the Paskapoo Formation by Carrigy (1971). However, because of the

Table 7-1 DISTRIBUTION OF SPECIES IN FORMATIONS OF WESTERN CANADA (Bell 1949:29-35)

	Bearpaw formation	St. Mary River formation	Edmonton formation (lower part)	Edmonton formation (upper part)	Brazeau formation (upper part)	Wapiti group	Post-Brazeau Paleocene beds	Willow Creek formation (upper part)	Porcupine Hills ? or Willow Creek	Paskapoo formation	Paskapoo equivalent in Mackenzie River Valley	Whitemud	Frenchman formation	Ravenscrag formation	Paleocene ? B.C. or Yukon
Phylum Euthallophyta															
Order Charales															
Family Characeae															
Aclistochara compressa								×							
Subphylum Pteridophyta															
Order Equisetales															
Family Equisetaceae															
Equisetum perlaevigatum		×	×												
E. alezoensis							×							×	
E. arcticum										×			×	×	
E. boreale							×			×					
Order Filicales															
Family Osmundaceae															
Osmunda macrophylla										×					
Cladophlebis groenlandica							×				×				
Family Dennstaedtiaceae															
Dennstaedtia blomstrandi										×				×	
Sphenopteris (Dennstaedtia?) burlingi						×									
Family Polypodiaceae															
Onoclea hebridica							×			×				×	
Dryopterites georgii ?													×		
Asplenium ? penhallowi										×					
Adiantum ? paululum		×													
Incertae sedis															
Filicites knowltoni				×											
Group Cycadophyta															
Incertae sedis															
Nilssonia serotina			×		×										
N. sp			×												
Carpolithus (Cycadinocarpus?) ceratops		×		×									×		

Table 7-1 DISTRIBUTION OF SPECIES IN FORMATIONS OF WESTERN CANADA (Bell 1949:29-35)

	Bearpaw formation	St. Mary River formation	Edmonton formation (lower part)	Edmonton formation (upper part)	Brazeau formation (upper part)	Wapiti group	Post-Brazeau Paleocene beds	Willow Creek formation (upper part)	Porcupine Hills ? or Willow Creek	Paskapoo formation	Paskapoo equivalent in Mackenzie River Valley	Whitemud	Frenchman formation	Ravenscrag formation	Paleocene ? B.C. or Yukon
Group Ginkgoales															
Family Ginkgoaceae															
Ginkgoites adiantoides						×				×		×	×	×	
G. sp.			×												
Carpolithus (Ginkgoites?) fultoni		?	×												
C. (Ginkgoites?) kneehillensis			×												
C. (Ginkgoites?) selwyni								×		×				×	
Group Coniferales															
Family Taxaceae															
Torreyites tyrrellii	×		×												
Elatocladus (Taxites?) olriki						×	×				×				
Androvettia catenulata								×		×					
Family Cupressaceae															
Pityostrobus (Cunninghamiostrobus?) sp.			×												
Sequoiites langsdorfii						?	×			×					
S. artus			×		×	×						×			
Elatocladus (Sequoiites?) ungeri															×
S. couttsiae ?															×
S. dakotensis			×	×		?							×		
Cryptomerites lambii							×			×				×	
Elatocladus (Cryptomerites?) nordenskioldi							×		×	×				×	
E. (Taxodites?) tinajorum								×						×	×
E. intermedius		×	×		×	×									
Thuites interruptus		×	×				×			×		×		×	
Juniperites gracilis			×												
Class Dicotyledones															
Order Fagales															
Family Betulaceae															
Alnus serrata														×	
Corylites fosteri										×					
Family Fagaceae															
Dryophyllum (Castanea?) sp.							×								
Quercus praegroenlandica							×								

Table 7-1 DISTRIBUTION OF SPECIES IN FORMATIONS OF WESTERN CANADA (Bell 1949:29-35)

	Bearpaw formation	St. Mary River formation	Edmonton formation (lower part)	Edmonton formation (upper part)	Brazeau formation (upper part)	Wapiti group	Post-Brazeau Paleocene beds	Willow Creek formation (upper part)	Porcupine Hills ? or Willow Creek	Paskapoo formation	Paskapoo equivalent in Mackenzie River Valley	Whitemud	Frenchman formation	Ravenscrag formation	Paleocene ? B.C. or Yukon
Order Juglandales															
Family Juglandaceae															
Juglans leconteana										X					
J. thermalis										X					
J. nigella														X	
Order Salicales															
Family Salicaceae															
Populus carneosa										X					
P. penhallowi										X					
P. ? daturaefolia										X					
Order Hamamelidales															
Family Cercidiphyllaceae															
Trochodendroides arctica			X		X	X				X	X	X	X	X	
Jenkinsella arctica			X			X				X		X		X	
Family Platanaceae															
Platanus basilobata										X				X	
P. raynoldsii							X	X	X	X				X	
P. raynoldsii integrifolia				X		X									
Platanophyllum sp.				X											
Order Ranales (Polycarpicae)															
Family Anonaceae															
Anona robusta				X											
Family Lauraceae															
Laurophyllum laraminum										X				X	
Family Menispermaceae															
Menispermites belli												X			
Dombeyopsis nebrascensis		X	X		X	X	X						X		
Family Nymphaeaceae															
Nelumbites protoluteus										X		X			
Nymphaeites angulatus		X	X	X		X	X			X		X		X	
N. striatus		X				?						X			
Antholithes (Nymphaeites ?) marsilioides		X													
Paranymphaea crassifolia							X			X				X	

Table 7-1 DISTRIBUTION OF SPECIES IN FORMATIONS OF WESTERN CANADA (Bell 1949:29-35)

	Bearpaw formation	St. Mary River formation	Edmonton formation (lower part)	Edmonton formation (upper part)	Brazeau formation (upper part)	Wapiti group	Post-Brazeau Paleocene beds	Willow Creek formation (upper part)	Porcupine Hills ? or Willow Creek	Paskapoo formation	Paskapoo equivalent in Mackenzie River Valley	Whitemud	Frenchman formation	Ravenscrag formation	Paleocene ? B.C. or Yukon
Order Rosales															
Incertae sedis															
Leguminosites stagnum		×													
Order Malvales															
Family Sterculiaceae															
Pterospermites whitei										×	×				
P. dawsoni										×				×	
P. haguei ?									×						
Order Sapindales (Terebinthales)															
Family Aceraceae															
Acer arcticum											×				
Order Celastrales															
Family Celastraceae															
Celastrinites insignis							×			×		×	×	×	
Order Rhamnales															
Family Rhamnaceae															
Rhamnites ovatus										×					
R. marginatus										×				×	
Zizyphoides colombi							×							×	
Z. mackayi							×								
Family Vitaceae															
Vitis stantoni			×	×								×			
Order Umbellales (Umbelliflorae)															
Family Cornaceae															
Cornus denverensis									×						
Family Avaliaceae															
Oreopanax ? sp							×								
Aralia alexoensis							×		×						
Family Lauraceae															
Laurophyllum laraminum										×				×	

Table 7-1 DISTRIBUTION OF SPECIES IN FORMATIONS OF WESTERN CANADA (Bell 1949:29-35)

	Bearpaw formation	St. Mary River formation	Edmonton formation (lower part)	Edmonton formation (upper part)	Brazeau formation (upper part)	Wapiti group	Post-Brazeau Paleocene beds	Willow Creek formation (upper part)	Porcupine Hills ? or Willow Creek	Paskapoo formation	Paskapoo equivalent in Mackenzie River Valley	Whitemud	Frenchman formation	Ravenscrag formation	Paleocene ? B.C. or Yukon
Family Menispermaceae															
Menispermites belli												X			
Dombeyopsis nebrascensis		X	X		X	X	X						X		
Order Ligustrales															
Family Oleaceae															
Fraxinus leii				X											
Order Rubiales															
Family Caprifoliaceae															
Viburnum antiquum									X					X	
V. simile					X							X			
V. trinervum									X					X	
V. lakesii									X						
V. asperum										X				X	
Incertae sedis															
Dicotylophyllum contractinervosum							X								
Nordenskioldia borealis											X				
Carpolithus symploeoides ?							X								
Class Monocotyledones															
Incertae sedis															
Majanthemophyllum grandifolium										X					
Cannophyllites magnifolia										X					
Order Spadiciflorea															
Family Araceae															
Pistia corrugata												X			
Family Lemnaceae															
Spirodela scutata					X		X			X				X	
Order Pandanales															
Family Typhaceae															
Typa sp.		X													

transitional nature of the contact of the Porcupine Hills Formation with the Willow Creek Formation and the conflict in terminology, these strata may well be equivalent to basal Porcupine Hills Formation strata. Fragments of turtle shells (*Aspiderites*) are present in the railroad cut immediately east of Edworthy Park, Calgary (personal observations) in strata mapped as Porcupine Hills Formation (Carrigy 1971). *Aspiderites* spp. was reported from the Elbow River (LSD3.4.24.1.W5M) by Russell (1929).

Crocodiles - Russell (1929) reported *Leidyosuchus*? sp from strata on the Elbow River, Calgary (LSD3.4.24.1.W5M) and Erickson's Landing, Red Deer River (23/24.38.26.W4M).

Champsosaurus - Russell (1929) reported *Champsosaurus* spp from the Paskapoo Formation on Willow Creek (LSD3.4.24.1.W5M).

Fossil Fish

Russell (1928) described a new genus and species of fossil fish (*Stylomyleodon lacus* Russell) from the Paskapoo Formation in the vicinity of the city of Red Deer. Subsequently, Russell (1929) reported the species from the right bank of the Elbow River (LSD3.4.24.1.W5M), on the left bank of the Bow River southwest of Cochrane (LSD7.4.26.4.W5M), and on the railroad cut about two kilometres east of Cochrane (LSD4.1.26.4.W5M). The latter two localities were assigned to the Porcupine Hills Formation (Dawson 1883; Carrigy 1971). Localities on the Elbow River could be low in the Porcupine Hills Formation or in immediately subjacent strata.

Russell (1929) notes that if the holotypes and paratypes of *Kindleia fragosa* D S Jordon pertain to a single genus, then *Stylomyleodon lacus* would be a synonym. This, however, does not alter the significant occurrence of this fossil within the Porcupine Hills Formation.

In addition to the above species, three specimens of *Lepisosteus* sp were recovered from sandstones in downtown Calgary. These undescribed specimens in the Department of Geology and Geophysics, University of Calgary, add a second fossil fish known to originate in this formation (M. C. Wilson, 1985, personal communication).

Fossil Mammals

Russell (1929, 1955-6) identified fossil mammals from several localities within the Paskapoo Formation. The findings are summarized below.

Locality: right bank Elbow River (LSD3.4.24.1.W5M)
Ectypodus cochranensis (Russell)
Catopsalis calgariensis Russell
Chriacus? sp
Neoclaenodon? sp
Parectypodus? sp
Tetraclaenodon Pronotodectes cf. *puercensis* (Cope)

Locality: right bank Elbow River (LSD1.32.23.1.W5)
Eucosmodon sp
Catopsalis calgariensis Russell

Locality: left bank Bow River (LSD7.4.26.4.W5M) southwest of Cochrane
Diacodon septentrionalis Russell
Ectypodus cochranensis (Russell)
Ectocion collinus Russell

Age: All of the above localities are in the uppermost Palaeocene Strata assigned to the Porcupine Hills Formation (Carrigy 1971).

Locality: Large railway cut ca. two kilometres east of Cochrane (LSD4.1.26.4.W5M), ca. eighteen metres above the railway track

Chriacus orthogonius Russell
Diacodon septentrionalis Russell
Diacodon cf. alticuspis Cope
Ectypodus cochranensis (Russell)
Leptacodon sp
Meniscotherium semicingulatum Russell
Ptilodus?

Age: Upper Palaeocene to lower Eocene. Strata now assigned to the Porcupine Hills Formation (Carrigy 1971).

Simpson (1927) reported the following mammals from the Paskapoo Formation near Red Deer (Ericksons Landing).

Catopsalis calgariensis Russell
Elpidophorus elegans Simpson
Nothodectes cf girdleyi Matthew
?Phenacodus sp
Propalaeosinopa albertensis

Krishtalka (1973) provides additional data on the occurrence of Palaeocene mammals from the Cypress Hills, Alberta.

Shelly Faunas: (Mollusca and Gastropoda)

Russell (1929) summarized the occurrence of shelly faunas within the Paskapoo and Porcupine Hills formations (Table 7-2) and concluded that with the exception of Oreohelix which is a terrestrial form, they represented a fresh water fauna. Tozer (1956) noted that the only determinable shelly fossils from the Porcupine Hills Formation were Grangerella mcleodensis (Russell) and Oreohelix thurstoni (Russell). However, his usage arbitrarily restricted the Porcupine Hills to the area south of Township 13.

Table 7-2 SHELL FAUNA COLLECTED FROM PASKAPOO BEDS (Russell 1929:136-137)

Unio priscus M. & H.
U. danae M. & H.
U. senectus White
Sphaerium aequale Russell
S. fowleri Russell
S. formosum M. & H.
Hydrobia anthonyi (M. & H.)
H. warrenana (M. & H.)
Micropyrgus minutulus (M. & H.)
Viviparus leai (M. & H.)
V. raynoldsanus M. & H.
V. retusus (M. & H.)
V. trochiformis (M. & H.)
V. planolatere Russell
Campeloma nebrascense whitei Russell
C. multistriatum (M. & H.)?
C. limnaeiforme (M. & H.)
Lioplax nebrascensis (M. & H.)
L. nebrascensis producta (White)
Valvata subumbilicata (M. & H.)
V. bicincta Whiteaves
Goniobasis tenuicarinata (M. & H.)
Lymnaea tenuicosta (M. & H.)
Physa canadensis parvaturris Russell
P. canadensis media Russell
P. canadensis ampla Russell
P. canadensis tenuis Russell
P. galei Russell
Ferrissia minuta (M. & H.)
F. radiatula (Whiteaves)
Pseudocolumna haydeniana (Cockerell)
P. vermicula (M. & H.)
Oreohelix thurstoni (Russell)

Ostracoda

Ostracods have been recovered from the Willow Creek and Porcupine Hills formations by Germundson (1965).

7.7 PREVIOUSLY RECORDED SITES

7.7.1 Recorded Prehistoric Sites

Ninety-six prehistoric sites were previously recorded in potential reservoir Site No. 1, Site No. 2, and Site No. 3. Fifty were recorded in Site No. 1, Willow Creek near Claresholm and forty-six were recorded in Site No. 2, Pine Coulee. No sites have been recorded in Site No. 3, Willow Creek near Lane/Kuntz Creek. Site No. 4 which includes all of Site No. 2 contains the forty-six sites recorded in Site No. 2 plus an additional four sites. The sites are referred to by a *Borden Number* assigned by the Archaeological Survey of Alberta, Alberta Culture. The site classifications as recorded on the site forms on file have been used without modification. The sites were plotted on maps of 1:50,000 scale by their Universal Transverse Mercator Grid (UTM) locations provided on the site forms. This system of location permits plotting of sites to the nearest one hundred metres. Sites lacking this locational data were not plotted.

7.7.1.1 Site No. 1, Willow Creek near Claresholm. Of the fifty previously recorded prehistoric sites in Site No. 1, Willow Creek near Claresholm, twenty-nine occur within the Full Supply Level (F.S.L.) as mapped by Klohn Leonoff Ltd. (1984) (Table 7-3; Figure 7-6; Appendix I).

The fifty sites have been assigned to various site types. Seven (N = 7) are buried campsites, seven (N = 7) are tipi rings, seven (N = 7) are cairns, five (N = 5) are bison jumps, four (N = 4) are drive lanes, four (N = 4) are surface camps, three (N = 3) are

Table 7-3 Previously Recorded Prehistoric Sites - Site No. 1 Willow Creek Near Claresholm

BORDEN UNIT	DESIGNATION	SITE TYPE	NTS	UTM	LEGAL DESCRIPTION	INSIDE F.S.L.	OUTSIDE F.S.L.
EaPk	4	Bison Kill	82I/4	12UUL069506	NE.NW.12.13.28.4	X	
EaPk	5	Burial Camp	82I/4	12UUL067505	SW.SW.13.13.28.4		X
EaPk	6	Bison Kill	82I/4	12UUL066505	NW.NW.12.13.28.4	X	
EaPk	7	Effigy/Hearth	82I/4	12UUL068517	NE.NW.13.13.28.4	X	
EaPk	8	Blowout	82I/4	12UUL075498	SE.NE.12.13.28.4	X	
EaPk	9	Surface Site	82I/4	12UUL074504	NW.NE.12.13.28.4		X
EaPk	10	Hearth	82I/4	12UUL069503	NW.NW.12.13.28.4	X	
EaPk	11	Kills/Burial	82I/4	12UUL073490-92	SW.SE.12.13.28.4	X	
EaPk	24	Bison Jump	82I/4	12UUL046536	NE.NE.22.13.28.4	X	
EaPk	31	Bison Jump	82I/4	12UUL	NE.SW.23.13.28.4		X
EaPk	34	Surface Site	82I/4	12UUL073485	W½.NE.23.13.28.4		X
EaPk	35	Bison Jump	82I/4	12UUL062474	SE.SE. 2.13.28.4		X
EaPk	36	Cairns	82I/4	12UUL049532	SE.NW.23.13.28.4	X	
EaPk	38	Pictographs	82I/4	12UUL	SE.NE.28.13.28.4		X
EaPk	50	Tipi Rings	82I/4	12UUL064481	NW.SW. 1.13.28.4		X
EaPk	64	Cairns	82I/4	12UUL063522	NE.NE.14.13.28.4		X
EaPk	65	Buried Camp	82I/4	12UUL059522	NW.NE.14.13.28.4	X	
EaPk	66	Buried Camp	82I/4	12UUL059520	NE.NE.14.13.28.4	X	
EaPk	67	Surface Camp	82I/4	12UUL060524	SE.SE.23.13.28.4		X
EaPk	68	Surface Camp	82I/4	12UUL056525	SW.SE.23.13.28.4	X	
EaPk	69	Cairn	82I/4	12UUL054528	NE.SW.23.13.28.4		X
EaPk	70	Buried Camp	82I/4	12UUL053526	SE.SW.13.13.28.4	X	
EaPk	71	Cairn/Campsite	82I/4	12UUL052530	NE.SW.23.13.28.4	X	
EaPk	72	Burial	82I/4	12UUL051527	NE.SW.23.13.28.4	X	

Table 7-3 Previously Recorded Prehistoric Sites - Site No. 1 Willow Creek near Claresholm (continued)

BORDEN UNIT	DESIGNATION	SITE TYPE	NTS	UTM	LEGAL DESCRIPTION	INSIDE F.S.L.	OUTSIDE F.S.L.
EaPk	73	Rock Shelter	82I/4	12UUL050529	NW.SW.23.13.28.4	X	
EaPk	74	Surface Camp	82I/4	12UUL049532	SW.NW.23.13.28.4		X
EaPk	75	Surface Camp	82I/4	12UUL048534	SE.NW.29.13.28.4	X	
EaPk	76	Killsite/Buried Camp	82I/4	12UUL046535	NE.NE.22.13.28.4	X	
EaPk	116	Buried Campsite	82I/4	12UUL038536	NW.NE.22.13.28.4	X	
EaPk	118	Tipi Rings	82I/4	12UUL	NW.NW.22.13.28.4		X
EaPk	119	Tipi Rings	82I/4	12UUL036535	NE.NW.22.13.28.4		X
EaPk	120	Tipi Rings	82I/4	12UUL037534	SE.NW.22.13.28.4		X
EaPk	121	Drive Lane	82I/4	12UUL	NE.SW.21.13.28.4		X
EaPk	122	Tipi Rings/Stone Alignment	82I/4	12UUL047527	NE.SE.22.13.28.4	X	
EaPk	123	Bison Kill Site	82I/4	12UUL038536	NW.NE.22.13.28.4	X	
EaPk	124	Rock Shelter	82I/4	12UUL040527	NW.SE.22.13.28.4	X	
EaPk	125	Bison Jump Site	82I/4	12UUL042527	NW.SE.22.13.28.4	X	
EaPk	126	Drive Lane	82I/4	12UUL	NE.NW.15.13.28.4		X
EaPk	127	Cairns	82I/4	12UUL036518	SE.NW.15.13.28.4		X
EaPk	128	Cairn	82I/4	12UUL040515	NE.SW.15.13.28.4		X
EaPk	129	Tipi Ring	82I/4	12UUL047527	NW.SW.23.13.28.4		X
EaPk	130	Tipi Rings	82I/4	12UUL	SW.SE.22.13.28.4		X
EaPk	131	Tipi Rings	82I/4	12UUL048525	SW.SW.23.13.28.4	X	
EaPk	132	Cairns	82I/4	12UUL	SW.SW.23.12.28.4		X
EaPk	133	Bison Jump	82I/4	12UUL050520	N½.14.13.28.4	X	
EaPk	134	Drive Lane	82I/4	12UUL050520	E½.NW.14.13.28.4	X	
EaPk	135	Drive Lanes	82I/4	12UUL	S½.22.13.28.4		X
EaPk	139	Buried Campsite	82I/4	12UUL063475	SW.SW. 1.13.28.4		X
EaPk	141	Cairns	82I/4	12UUL053516	SE.NW.14.13.28.4		X
EaPk	169	Buried Camp	82I/4	12UUL061518	SE.NE.14.13.28.4	X	

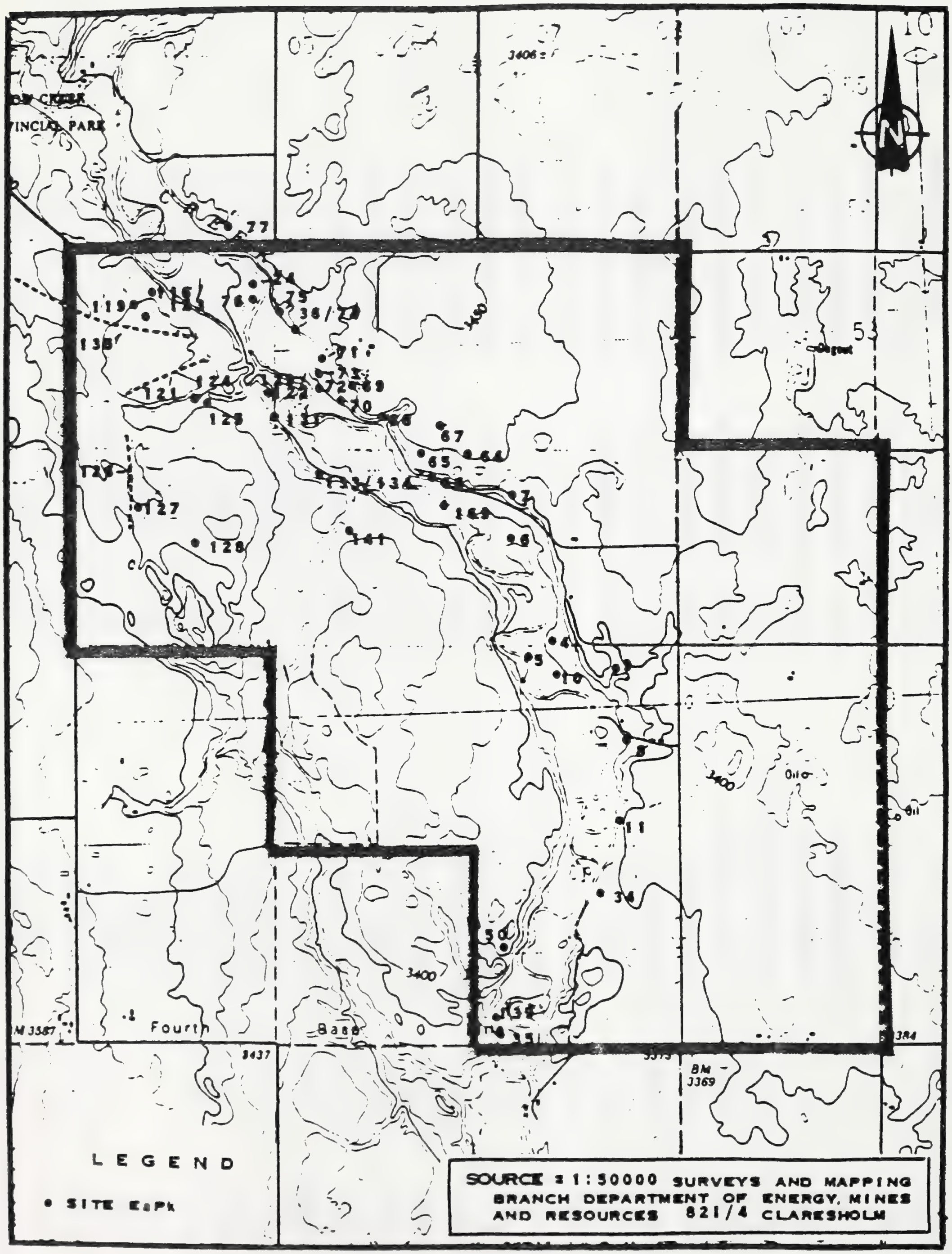


Figure 7-6 PREVIOUSLY RECORDED PREHISTORIC SITES - SITE NO. 1

bison kills, two (N = 2) are rock shelters, one (N = 1) is an effigy/hearth, one (N = 1) is a blowout, one (N = 1) is a surface scatter, one (N = 1) is a hearth, one (N = 1) is a kill/burial, one (N = 1) is a surface site, one (N = 1) is a pictograph, one (N = 1) is a cairn/campsite, one (N = 1) is a burial, one (N = 1) is a kill site/buried camp, and one (N = 1) is a tipi ring/stone alignment.

7.7.1.2 Site No. 2, Pine Coulee. Forty-six prehistoric sites are situated in the Pine Coulee reservoir study area (Table 7-4; Figure 7-7; Appendix I). None occur within the F.S.L. However, UTM locations are not available for all sites.

Nine (N = 9) are cairns, seven (N = 7) are tipi rings, four (N = 4) are surface sites, three (N = 3) are campsites, three (N = 3) are rock alignments, two (N = 2) are campsites/tipi rings, one (N = 1) is a rock shelter, one (N = 1) is a surface hearth, one (N = 1) is a drive lane, one (N = 1) is a sandstone outcrop, one (N = 1) is a stone circles/cairn, one (N = 1) is a rock alignment/tipi rings, one (N = 1) is a tipi rings/cairn, one (N = 1) is a bison kill/campsite, one (N = 1) is a buried campsite, one (N = 1) is a bison jump, one (N = 1) is a buffalo effigy/rock alignment, one (N = 1) is a stone circle/lithic scatter, one (N = 1) is a isolated find, one (N = 1) is a lithic scatter, one (N = 1) is a bison kill, one (N = 1) is a pictograph, one (N = 1) is a small lithic scatter, one (N = 1) is an unknown site type.

7.7.1.3 Site No 3, Willow Creek near Lane Creek/Kuntz Creek. No previously recorded prehistoric sites occur in potential reservoir Site No. 3, Willow Creek near Lane Creek/Kuntz Creek.

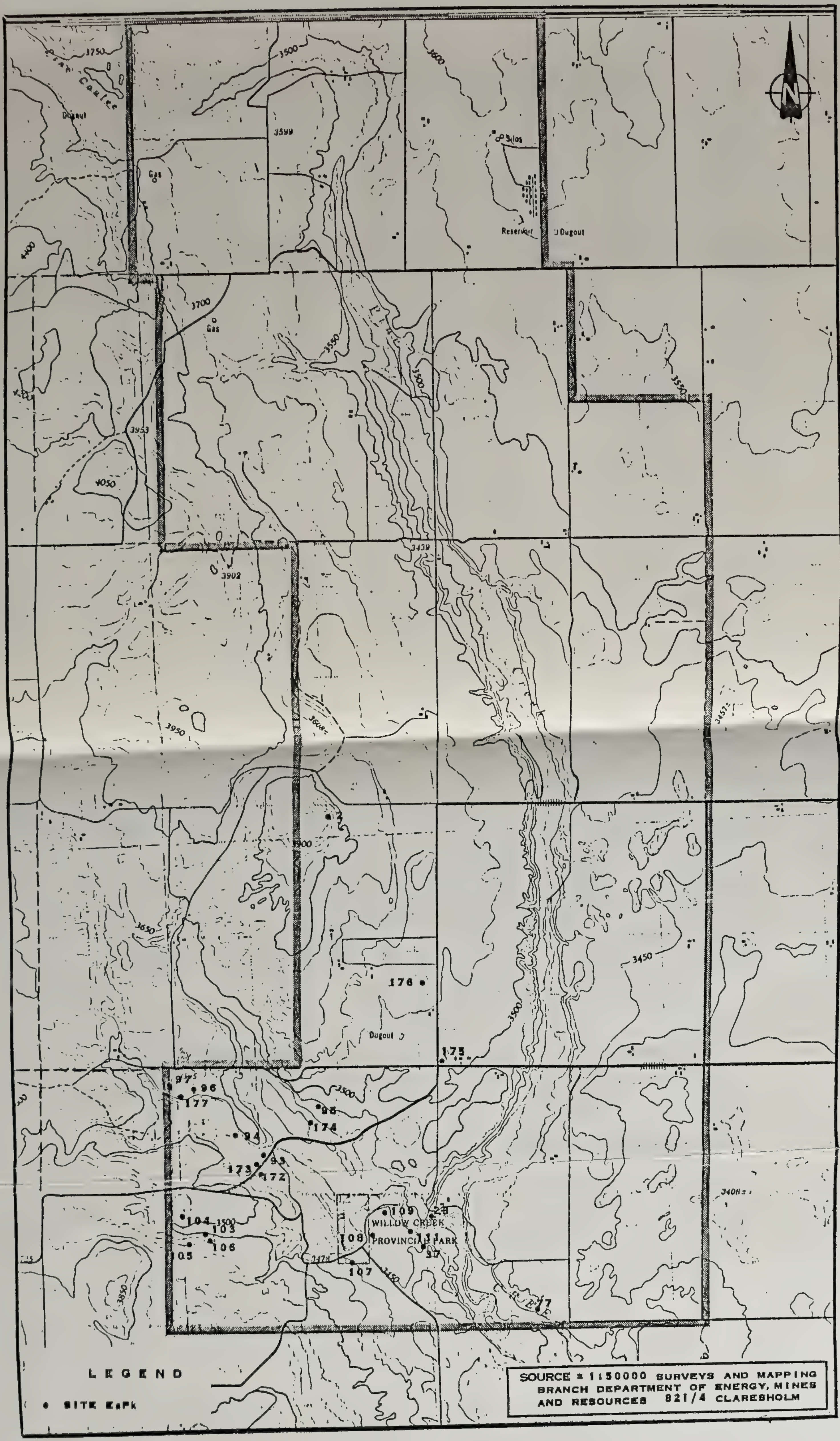
7.7.1.4 Site No. 4, Pine Coulee/Willow Creek. Of the fifty previously recorded prehistoric sites in Site No. 4, Pine

Table 7-4 Previously Recorded Prehistoric Sites - Site No. 2 Pine Coulee

BORDEN UNIT	DESIGNATION	SITE TYPE	NTS	UTM	LEGAL DESCRIPTION	INSIDE F.S.L.	OUTSIDE F.S.L.
EaPk	2	Rock Shelter	82I/4	12UUL020603	NW.NW. 9.14.28.4		X
EaPk	23	Surface Hearth	82I/4	12UUL	NE.NE.28.13.28.4		X
EaPk	37	Drive Lanes	82I/4	12UUL030549	SE.NE.28.13.28.4		X
EaPk	39	Rock Alignment	82I/4	12UUL	NE.SE.28.13.28.4		X
EaPk	77	Cairn	82I/4	12UUL044541	SW.SE.27.13.28.4		X
EaPk	78	Surface Site	82I/4	12UUL	E½.N½.27.13.28.4		X
EaPk	79	Surface Site	82I/4	12UUL	NE.NW.27.13.28.4		X
EaPk	80	Surface Site	82I/4	12UUL	NW.NW.27.13.28.4		X
EaPk	81	Cairn	82I/4	12UUL	NE.NE.28.13.28.4		X
EaPk	82	Tipi Rings	82I/4	12UUL	NE.SW.34.13.28.4		X
EaPk	83	Cairns	82I/4	12UUL	NE.SW.34.13.28.4		X
EaPk	84	Cairns	82I/4	12UUL	SW.SE.27.13.28.4		X
EaPk	85	Sandstone Outcrop	82I/4	12UUL	SE.SW.27.13.28.4		X
EaPk	86	Tipi Rings	82I/4	12UUL	SW.SE.33.13.28.4		X
EaPk	87	Campsite/Tipi Ring	82I/4	12UUL	SW.SE.33.13.28.4		X
EaPk	88	Cairn	82I/4	12UUL	NE.SW.33.13.28.4		X
EaPk	89	Tipi Ring	82I/4	12UUL	NE.SW.33.13.28.4		X
EaPk	90	Tipi Ring	82I/4	12UUL	SE.SW.33.13.28.4		X
EaPk	91	Campsite	82I/4	12UUL	NW.NW.28.13.28.4		X
EaPk	92	Campsite/Tipi Ring	82I/4	12UUL	SE.NW.28.13.28.4		X
EaPk	93	Tipi Ring	82I/4	12UUL011560	NW.SE.32.13.28.4		X
EaPk	94	Surface Site	82I/4	12UUL008564	SW.NE.32.13.28.4		X
EaPk	95	Campsite	82I/4	12UUL007568	SE.NW.32.13.28.4		X

Table 7-4 Previously Recorded Prehistoric Sites - Site No. 2 Pine Coulee (continued)

BORDEN UNIT	DESIGNATION	SITE TYPE	NTS	UTM	LEGAL DESCRIPTION	INSIDE F.S.L.	OUTSIDE F.S.L.
EaPk	96	Stone Circles/Cairns	82I/4	12UUL000-03 569-72	N½.NW.32.13.28.4		X
EaPk	103	Cairns	82I/4	12UUL004552	NE.NW.29.13.28.4		X
EaPk	104	Cairn	82I/4	12UUL000554	NW.NW.29.13.28.4		X
EaPk	105	Cairn	82I/4	12UUL001550	SW.NW.29.13.28.4		X
EaPk	106	Rock Alignment	82I/4	12UUL004551	SE.NW.29.13.28.4		X
EaPk	107	Rock Alignment/Tipi Rings	82I/4	12UUL021547	NE.SW.28.13.28.4		X
EaPk	108	Tipi Rings and Cairns	82I/4	12UUL024550	SW.NE.28.13.28.4		X
EaPk	109	Bison Kill and Campsite	82I/4	12UUL026553	NW.NE.28.13.28.4		X
EaPk	110	Buried Campsite	82I/4	12UUL	NW.SW.27.13.28.4		X
EaPk	111	Bison Jump	82I/4	12UUL028-31 550-51	E½.NE.28.13.28.4		X
EaPk	112	Cairn	82I/4	12UUL	SW.SW.27.13.28.4		X
EaPk	113	Tipi Ring	82I/4	12UUL	SW.SW.27.13.28.4		X
EaPk	114	Tipi Rings	82I/4	12UUL	NE.SE.28.13.28.4		X
EaPk	115	Rock Alignment (Buffalo Effigy)	82I/4	12UUL	NE.SE.28.13.28.4		X
EaPk	117	Rock Alignment	82I/4	12UUL	SW.SW.27.13.28.4		X
EaPk	172	Camspite	82I/4	12UUL011559	N½.SE.32.13.28.4		X
EaPk	173	Stone Circle/Lithic Scatter	82I/4	12UUL010560	NW.SE.32.13.28.4		X
EaPk	174	Isolated Find	82I/4	12UUL017565	SW.NE.33.13.28.4		X
EaPk	176	Lithic Scatter	82I/4	12UUL032582	SE.NE. 4.14.28.4		X
EbPk	4	Buffalo Kill	82I/4	12UUL02 67	SE.SW. 3.15.28.4		X
EbPk	6	Petrograph	82I/4	12UUL02 69	NW.SE.10.15.28.5		X
EbPk	8	Unknown (Depression)	82I/4	12UUL02 62	SW.SW.21.14.28.4		X
EdPk	175	Small Lithic Scatter	82I/4	12UUL033572	SW.SW. 3.14.28.4		X



SOURCE = 1:50000 SURVEYS AND MAPPING BRANCH DEPARTMENT OF ENERGY, MINES AND RESOURCES 82I/4 CLARESHOLM

Figure 7-7 PREVIOUSLY RECORDED PREHISTORIC SITES - SITE NO. 2

Coulee/Willow Creek, seven occur within the Full Supply Level (F.S.L.) (Table 7-5; Figure 7-8); Appendix III).

In addition to the site types identified in Section 7.7.1.1 above which are also relevant to Site No. 4, one (N = 1) surface campsite, one (N = 1) is a buried campsite, one (N = 1) is a campsite, and one (N = 1) is a cairn.

7.7.2 Recorded Historic Sites

One previously recorded site was identified in the site records on file at the Historic Sites Service, Alberta Culture.

7.7.2.1 Site No. 1, Willow Creek near Claresholm. No previously recorded historic sites in potential reservoir Site No. 1, Willow Creek near Claresholm were identified in the site records on file at the Historic Sites Service, Alberta Culture.

7.7.2.2 Site No. 2, Pine Coulee. One previously recorded historic site occurs in Site No. 2, Pine Coulee (Figure 7-9; Appendix II, EaPk 39). It consists of two rectangular pitlike structures set into the side of a hill immediately south of a sandstone outcrop. Fragments of crockery and glass were observed scattered near the base of the slope near the structures.

7.7.2.3 Site No. 3, Willow Creek near Lane Creek/Kuntz Creek. No previously recorded historic sites occur in potential reservoir Site No. 3, Willow Creek near Lane Creek/Kuntz Creek.

7.7.2.4 Site No. 4, Pine Coulee/Willow Creek. One previously recorded historic site occurs in Site No. 4, Pine Coulee/Willow Creek (Figure 7-10). It also occurs in Site No. 2, Pine Coulee (see 7.7.2.2 above).

Table 7-5 Previously Recorded Prehistoric Sites - Site No. 4 Pine Coulee/Willow Creek

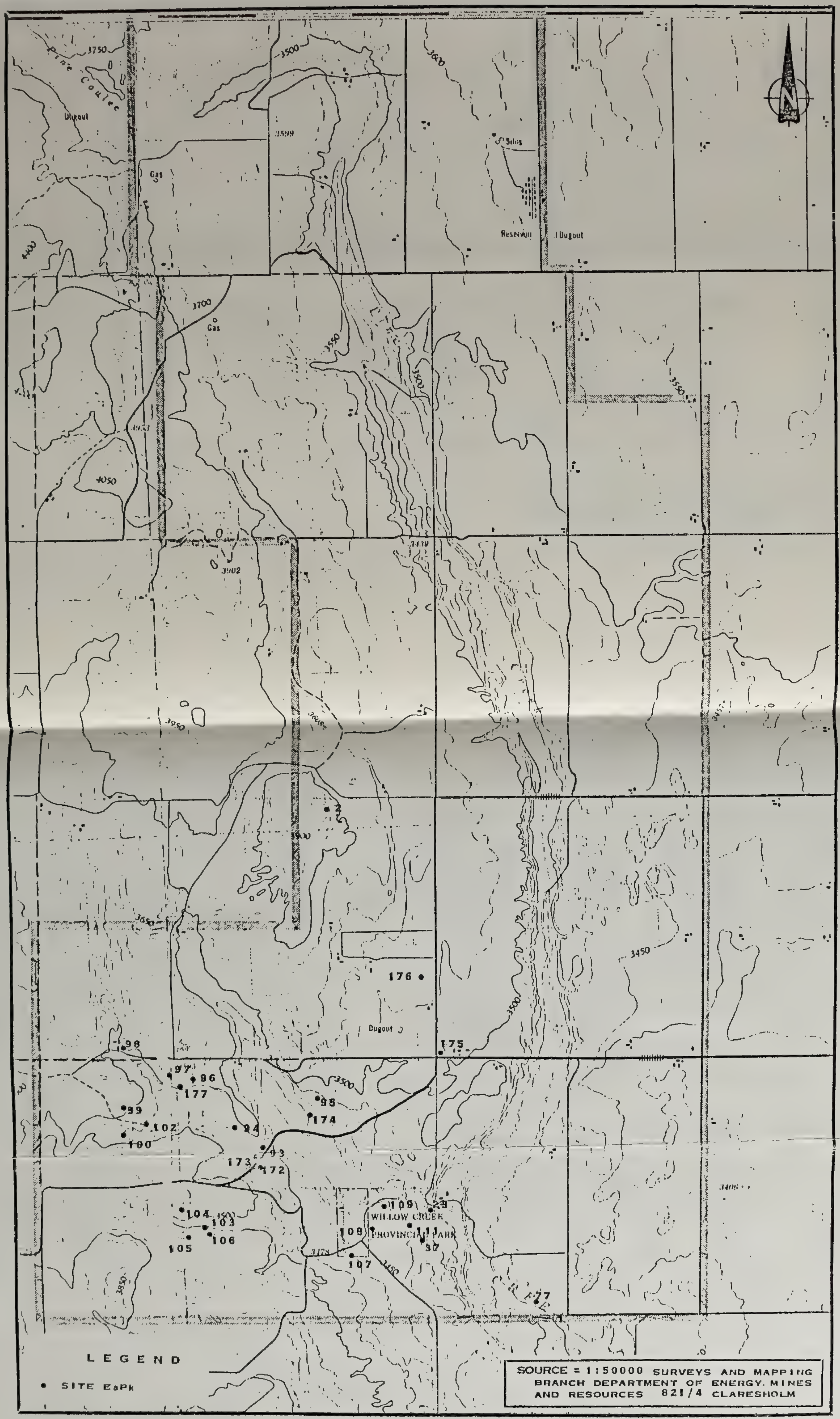
BORDEN UNIT	DESIGNATION	SITE TYPE	NTS	UTM	LEGAL DESCRIPTION	INSIDE F.S.L.	OUTSIDE F.S.L.
EaPk	2	Rock Shelter	82I/4	12UUL020603	NW.NW. 9.14.28.4		X
EaPk	23	Surface Hearth	82I/4	12UUL	NE.NE.28.13.28.4	X	
EaPk	37	Drive Lanes	82I/4	12UUL030549	SE.NE.28.13.28.4		X
EaPk	39	Rock Alignment	82I/4	12UUL	NE.SE.28.13.28.4		X
EaPk	77	Cairn	82I/4	12UUL044541	SW.SE.27.13.28.4		X
EaPk	78	Surface Site	82I/4	12UUL	E½.N½.27.13.28.4		X
EaPk	79	Surface Site	82I/4	12UUL	NE.NW.27.13.28.4		X
EaPk	80	Surface Site	82I/4	12UUL	NW.NW.27.13.28.4		X
EaPk	81	Cairn	82I/4	12UUL	NE.NE.28.13.28.4		X
EaPk	82	Tipi Rings	82I/4	12UUL	NE.SW.34.13.28.4		X
EaPk	83	Cairns	82I/4	12UUL	NE.SW.34.13.28.4		X
EaPk	84	Cairns	82I/4	12UUL	SW.SE.27.13.28.4		X
EaPk	85	Sandstone Outcrop	82I/4	12UUL	SE.SW.27.13.28.4		X
EaPk	86	Tipi Rings	82I/4	12UUL	SW.SE.33.13.28.4		X
EaPk	87	Campsite/Tipi Ring	82I/4	12UUL	SW.SE.33.13.28.4		X
EaPk	88	Cairn	82I/4	12UUL	NE.SW.33.13.28.4		X
EaPk	89	Tipi Ring	82I/4	12UUL	NE.SW.33.13.28.4		X

Table 7-5 Previously Recorded Prehistoric Sites - Site No. 4 Pine Coulee/Willow Creek (continued)

BORDEN UNIT	DESIGNATION	SITE TYPE	NTS	UTM	LEGAL DESCRIPTION	INSIDE F.S.L.	OUTSIDE F.S.L.
EaPk	90	Tipi Ring	82I/4	12UUL	SE.SW.33.13.28.4		X
EaPk	91	Campsite	82I/4	12UUL	NW.NW.28.13.28.4		X
EaPk	92	Campsite/Tipi Ring	82I/4	12UUL	SE.NW.28.13.28.4		X
EaPk	93	Tipi Ring	82I/4	12UUL011560	NW.SE.32.13.28.4	X	
EaPk	94	Surface Site	82I/4	12UUL008564	SW.NE.32.13.28.4	X	
EaPk	95	Campsite	82I/4	12UUL007568	SE.NW.32.13.28.4		X
EaPk	96	Stone Circles/Cairns	82I/4	12UUL000-03 569-72	N½.NW.32.13.28.4		X
EaPk	98	Surface Campsite	82I/4	12UTL994575	SW.SE. 6.14.28.4		X
EaPk	99	Cairns	82I/4	12UTL994567	SW.NE.31.13.28.4		X
EaPk	100	Buried Campsite	82I/4	12UTL994564	SW.NE.31.13.28.4		X
EaPk	102	Campsite	82I/4	12UTL996564	SE.NE.31.13.28.4		X
EaPk	103	Cairns	82I/4	12UUL004552	NE.NW.29.13.28.4		X
EaPk	104	Cairn	82I/4	12UUL000554	NW.NW.29.13.28.4		X
EaPk	105	Cairn	82I/4	12UUL001550	SW.NW.29.13.28.4		X
EaPk	106	Rock Alignment	82I/4	12UUL004551	SE.NW.29.13.28.4		X
EaPk	107	Rock Alignment/Tipi Rings	82I/4	12UUL021547	NE.SW.28.13.28.4		X
EaPk	108	Tipi Rings and Cairns	82I/4	12UUL024550	SW.NE.28.13.28.4		X
EaPk	109	Bison Kill and Campsite	82I/4	12UUL026553	NW.NE.28.13.28.4	X	

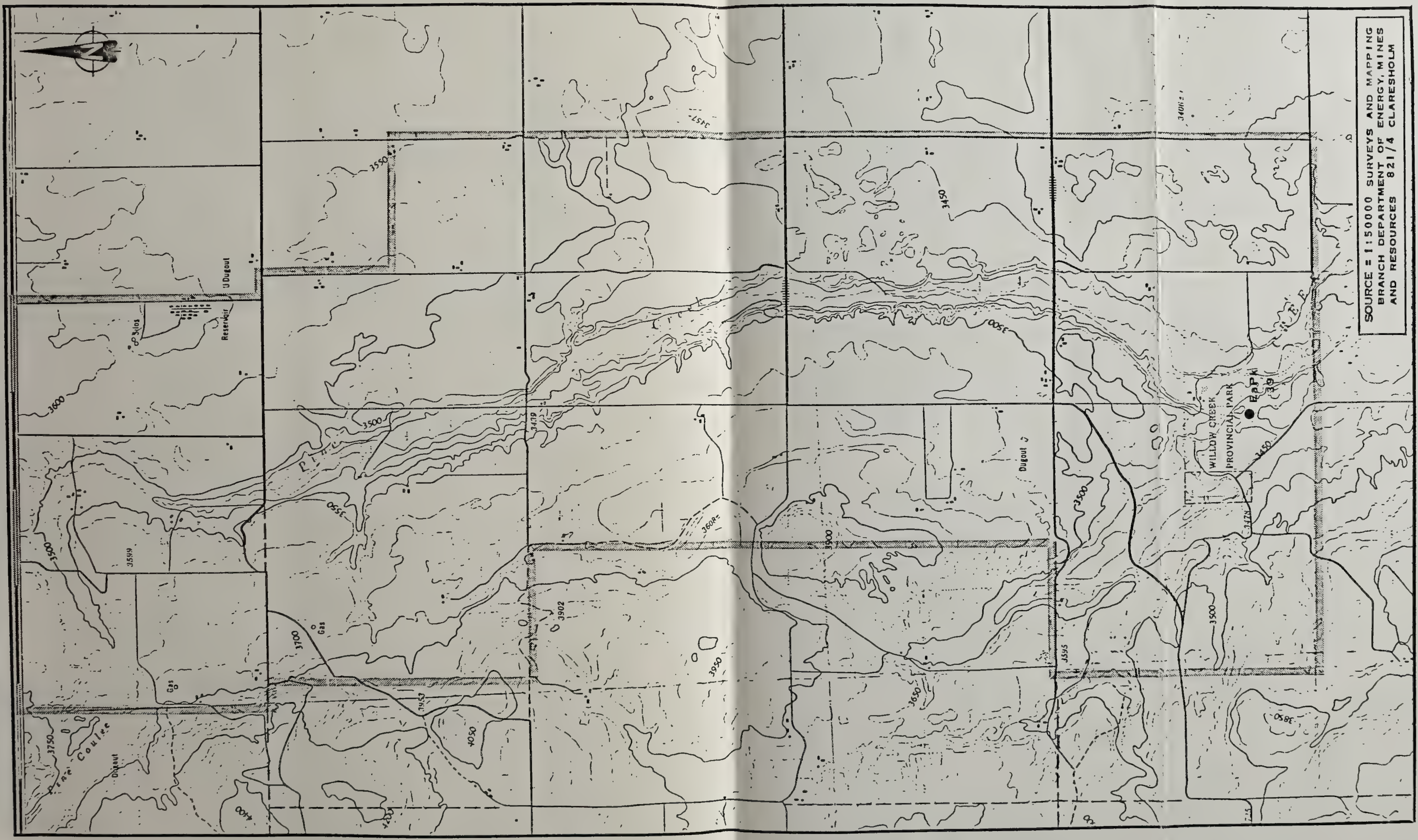
Table 7-5 Previously Recorded Prehistoric Sites - Site No. 4 Pine Coulee/Willow Creek (continued)

BORDEN UNIT	DESIGNATION	SITE TYPE	NTS	UTM	LEGAL DESCRIPTION	INSIDE F.S.L.	OUTSIDE F.S.L.
EaPk	110	Buried Campsite	82I/4	12UUL	NW.SW.27.13.28.4		X
EaPk	111	Bison Jump	82I/4	12UUL028-31 550-51	E½.NE.28.13.28.4	X	
EaPk	112	Cairn	82I/4	12UUL	SW.SW.27.13.28.4		X
EaPk	113	Tipi Ring	82I/4	12UUL	SW.SW.27.13.28.4		X
EaPk	114	Tipi Rings	82I/4	12UUL	NE.SE.28.13.28.4		X
EaPk	115	Rock Alignment (Buffalo Effigy)	82I/4	12UUL	NE.SE.28.13.28.4		X
EaPk	117	Rock Alignment	82I/4	12UUL	SW.SW.27.13.28.4		X
EaPk	172	Camspite	82I/4	12UUL011559	N½.SE.32.13.28.4	X	
EaPk	173	Stone Circle/Lithic Scatter	82I/4	12UUL010560	NW.SE.32.13.28.4	X	
EaPk	174	Isolated Find	82I/4	12UUL017565	SW.NE.33.13.28.4		X
EaPk	176	Lithic Scatter	82I/4	12UUL032582	SE.NE. 4.14.28.4		X
EbPk	4	Buffalo Kill	82I/4	12UUL02 67	SE.SW. 3.15.28.4		X
EbPk	6	Petrograph	82I/4	12UUL02 69	NW.SE.10.15.28.5		X
EbPk	8	Unknown (Depression)	82I/4	12UUL02 62	SW.SW.21.14.28.4		X
EdPk	175	Small Lithic Scatter	82I/4	12UUL033572	SW.SW. 3.14.28.4		X



SOURCE = 1:50000 SURVEYS AND MAPPING BRANCH DEPARTMENT OF ENERGY, MINES AND RESOURCES 82I/4 CLARESHOLM

Figure 7-8 PREVIOUSLY RECORDED PREHISTORIC SITES - SITE NO. 4



SOURCE = 1:50000 SURVEYS AND MAPPING BRANCH DEPARTMENT OF ENERGY, MINES AND RESOURCES 82I/4 CLARESHOLM

Figure 7-9 PREVIOUSLY RECORDED HISTORIC SITES - SITE NO. 2

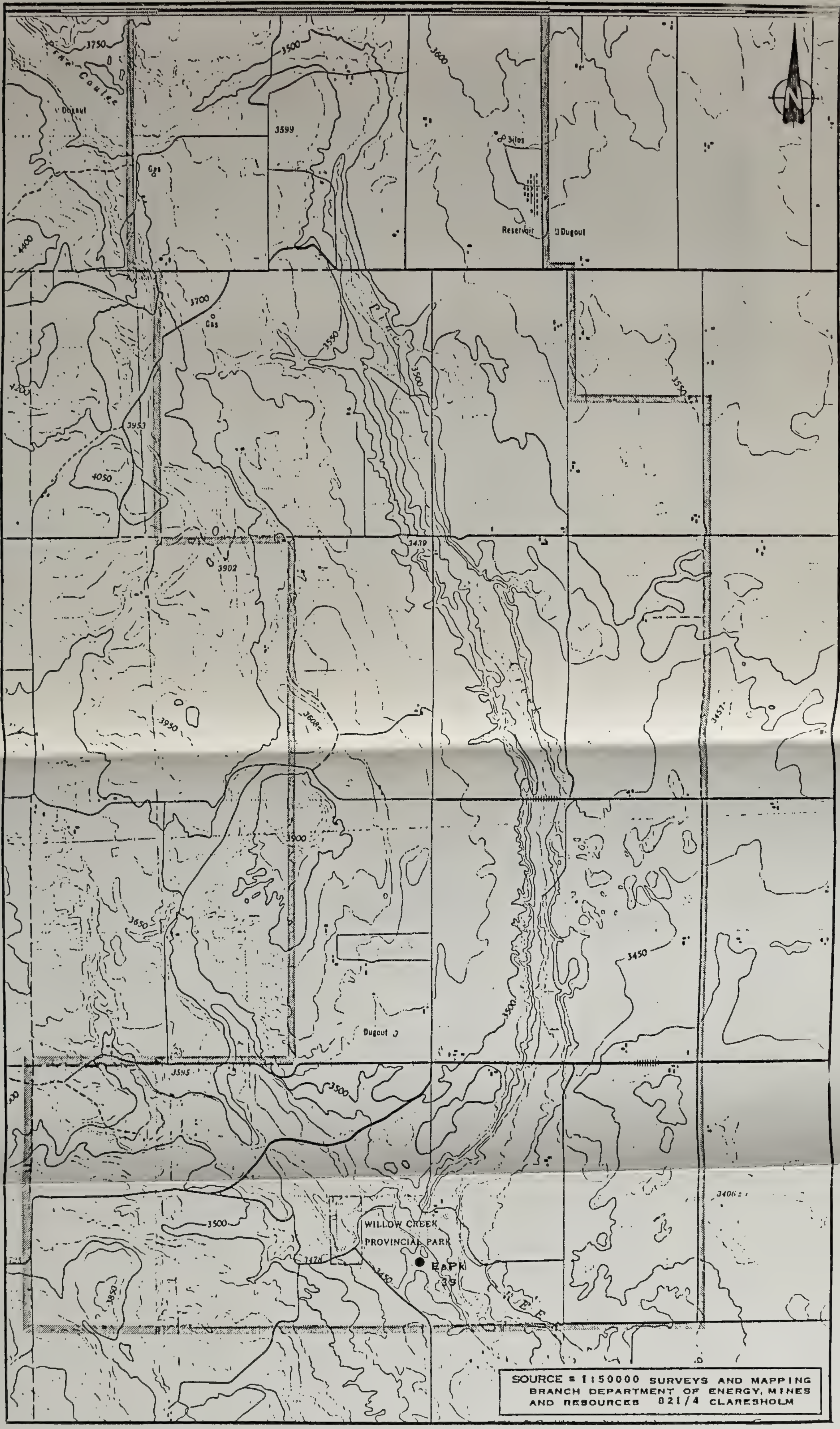


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Figure 7-10 PREVIOUSLY RECORDED SITES - SITE NO. 4

7.7.3 Recorded Palaeontological Sites

No identified collecting localities have previously been identified in any of the four potential reservoir areas.

7.8 SITE EVALUATION

7.8.1 Prehistoric Sites

The prehistoric site files indicate that the information for previously recorded sites in the four reservoir areas represents mere inventory data on site locations. The sites have not been assessed for their potential to contribute significant information to either the local or regional prehistory. In addition, some of the sites recorded represent only potential site locations.

Information on site contents, site size, and relationships is limited. For example, the extent of the recorded drive lanes was not mapped and their nature and relationship to other sites was not established. The descriptions of most sites provided in the site files are ambiguous, for example, "a diffuse scatter of flakes", "butchered bone observed", "bones were observed", "bone, firebroken rock and a hearth were observed", "concentrated scatter of rocks", and lack quantifiable or qualifiable information to indicate the true nature and extent of the cultural remains. Few stone circle sites were adequately documented as to number, size, and relationship of individual features. Stone circle sites vary widely in significance, depending on the nature and extent of the associated cultural material. Tipi rings with a high artifact yield are of high significance because they can provide information as to the cultural identity of the occupants, the economic activities conducted at the time of occupation, and the date of the occupation. Similarly, other sites such as those classified as buried campsites, surface campsites, and isolated finds require additional information to adequately assess their nature and extent and relative significance. A valid estimate of the significance of the previously recorded sites can only be determined through a program of field verification and limited test excavation.

In order to develop an effective management plan for any of the four proposed reservoir locations, it is necessary to obtain more detailed information as to the size, structure, and relationships of many of the individual sites. Attempting to evaluate the significance of these sites without adequate description and assessment would result in extremely tenuous site values. An example of the potential problems which can be encountered in attempting to assess the potential significance of previously recorded sites in the Willow Creek basin is found in the Gordon Site Complex. Two separate sites, EaPk 96 and EaPk 97, were originally recorded at the confluence of Oxley Creek and Willow Creek. EaPk 96 was described as consisting of two cairns and other rock piles. EaPk 97 was described as consisting of two tipi rings. Recent cursory re-examination of the site areas resulted in the identification of a minimum of five stone circles and four cairns and substantial subsurface cultural remains between the previously identified features of the two sites which suggested that the two 'sites' were a part of a single site complex (Fedirchuk 1985). Based on these findings, the significance of the Gordon Complex was re-evaluated and substantial mitigative studies were required.

However, based on past experience with prehistoric site structure and content, broad generalizations can be made as to potential site significance. For example, the drive lane/kill site complexes generally have high potential significance because of the probability of encountering well stratified remains which can be used to establish cultural sequences. Similarly, buried campsites are important because of their undisturbed context which permits identification of internal cultural patterning. Pictographs, effigies, and burials sites are important because they are generally unique sites and reflect the 'abstract' ideologies of prehistoric man. Rock shelters are unique site locations in Alberta and are of potentially high significance because of the possibility of finding extremely early associated cultural remains. Surface campsites, surface scatters, lithic scatters, and isolated finds, because of their disturbed context generally have limited value. Tipi rings/stone circles are of varying value. If these features are associated with low artifact yields, they are generally assigned a low value. Cairns, unless associated with burials or other stone configurations, e.g. medicine wheels, are also of generally low archaeological significance. It should be noted, however, that if complexes or clusters of any of these features/sites are found, the associations may be perceived to be of higher value when the features are viewed as a whole rather than as isolated features/sites.

7.8.2 Historic Sites

The historic structure recorded in Site No. 2, Pine Coulee and in Site No. 4, Pine Coulee/Willow Creek, has been insufficiently documented and researched. The location of the site, however, suggests that it may be associated with the illegal whiskey trade in the area. Additional field investigations are necessary to verify the identity of the site and its potential significance relative to the "Master Plan: Prehistoric and Historic Resources" developed by Alberta Culture for the protection and development of prehistoric and historic resources of Alberta.

7.9 HISTORICAL RESOURCES POTENTIAL

7.9.1 Prehistoric Resources

Based on early historic records and the known distribution of archaeological sites in other areas along the Eastern Slopes, numerous sites can be expected to occur in the study areas. Tipi rings frequently occur along the edges of streams, coulees, and prairie edges in the Eastern Slopes. Similarly, kill sites related to intensive exploitation of bison, can be expected to occur along the base of steep slopes and coulee systems. Bedrock outcrops are common locations for pictographs and petroglyphs and suitable lithic materials may have been mined for manufacture of tools and weapons. Ethnographic reports and archaeological studies indicate that crevices served as burial sites. Ceremonial sites such as Mystic Cave, situated in a sandstone outcropping west of Nanton, have been recorded in the general region and may be expected in the study areas. Because the four potential reservoir sites are situated within the Eastern Slopes which forms a transitional zone between the plains and the montane areas, a complex cultural history reflecting varying use patterns, communication patterns, and culture contact between the regions to the east and west is expected. Additionally, the direct association of each of the four reservoir sites with streams indicates that the prehistoric resource potential of each of the reservoirs is high.

The projected historical resources potential of each of the four reservoir sites is restricted to the area within the Full Supply Level. Based on the results of previous studies, reservoir Site No. 1, Willow Creek near Claresholm, is demonstrated to have high prehistoric site potential. The sites reflect a wide variety of activities and their locations suggest intensive use of the entire environs of Willow Creek in the prehistoric past. The distribution and nature of sites recorded indicate that additional sites can be expected to occur. A thin veneer of recently deposited gravel covers much of the valley floor. Few sites were previously recorded in this zone. Undiscovered sites may lie deeply buried below the gravel cover. Some of the valley rim has been disturbed by ploughing and sites found in these areas are unlikely to constitute significant historical resources. However, agriculturally inaccessible locations along the valley rim can be expected to contain stone circle, cairn, and other stone feature sites. Extensive bedrock exposures occur along the valley walls which are potentially associated with pictograph sites and burials. The numerous steep escarpments occurring along the valley edge are potential locations for prehistoric bison jumps/kills.

Although forty-six previously recorded prehistoric sites were identified in the Pine Coulee reservoir (Site No. 2) through the site file search, all sites with UTM locations are situated within the one mile buffer zone and not within the F.S.L. Based on recorded site distributions, the historical resource potential of the area within the F.S.L. of the Pine Coulee reservoir is best identified as a data gap. However, based on past experience and the character of Pine Coulee, some estimate of the prehistoric resource potential can be made.

Pine Coulee valley is distinct from the Willow Creek valley. Colluvial activity in Pine Coulee reservoir is extensive, no steep escarpments are present, and few bedrock outcrops occur. The morphology of Pine Coulee indicates a high velocity stream associated with steep valley walls along which extensive colluvial action has occurred. A number of small intermittent streams enter the coulee within the reservoir which would have resulted in the formation of small alluvial fans blocking the drainage of Pine Creek and forming small intermittent lakes. It is likely that prehistoric man would have camped along the shores of these lakes, utilized the surrounding valley floor, left kill site remains along the base of the escarpments, and perhaps left pictographs and petroglyphs on the exposed bedrock outcrops. With time, colluvial activity and alluvial deposition would have resulted in the deep burial of these sites. Later stone feature sites such as tipi rings and cairns which are highly visible, as well as campsites may be expected to occur along the valley rim. Most of the valley floor and and the valley rim have been ploughed in the past, obliterating any evidence of surficial stone feature sites. Because Pine Coulee may represent an early unglaciated meltwater channel predating the last period of deglaciation (i.e. late Illinoisan), the potential for extremely early prehistoric sites also exists.

No previously recorded sites are found in Site No. 3, Willow Creek near Lane/Kuntz Creek. This situation is a result of the lack of previous archaeological investigations rather than a reflection of the prehistoric resource potential of the area. The project prehistoric site potential is similar to that of Willow Creek near Claresholm. There are, however, few bedrock outcrops in Site No. 3, suggesting a lower potential for pictograph and burial sites. Limited potential for sites exists along the steeply sloping sections of the south wall of the valley. There is potential for deeply buried soils/sites along the river valley based on observations made during the overflight. Stone feature sites would be expected in the same general topographic localities as noted for reservoir Sites No. 1 and 2.

Fifty prehistoric sites were previously recorded in Site No. 4, Pine Coulee/Willow Creek. The prehistoric site potential of that portion of the proposed reservoir which is coterminus with Site No. 2, Pine Coulee, is identical to the latter site with respect to prehistoric resources. The portion of Site No. 4 enclosing the confluence and upstream portion of Willow Creek is expected to have a prehistoric resource potential more similar to Site No. 1, Willow Creek, in which stone feature sites, pictograph, and burial sites and bison jumps/kills are likely to occur.

7.9.2 Historic Sites

The Leavings site complex, although not on file at the Historic Sites Service, Alberta Culture, is of major historic importance in Site No. 1, Willow Creek near Claresholm. It represents two major themes in the development of southern Alberta: the North West Mounted Police and Ranching, as identified in the Alberta Culture Master Plan. The site complex encompasses a rather large locality and includes a portion of the Macleod Trail and numerous associated camps, Kountz' "Trading Post/Stopping House", the first Oxley Ranch headquarters, a North West Mounted Police Post, and a Stagecoach Relay Station.

Current evidence indicates that there are two early buildings still extant at The Leavings (NE.14.13.28.4 currently owned by A. Maurushat), a log house/barracks and a barn (Tatro 1974; Gardner 1975) which were used by the North West Mounted Police. The barracks are described as "a well built log building that has a siding veneer over all walls except the south and east walls of the eastern portion. There are remnants of shingle left in places over the siding. It is presently being used for storage but was the landowners residence until 1964. There is no evidence of a foundation and some of the base logs are rotting. The interior is essentially .... Just to the south of the building is a flag pole base. ...The barn, just NE of the barracks, is even a more unique building. It has been dug into the side hill and the lower walls are comprised of huge sandstone slabs cemented in place. ... On one of these slabs is inscribed the date 1884. The frame of the upper floor or loft is constructed of hand hewn timbers. The joints of martise [sic] and tenon ... are of the finest craftsmanship of any woodwork noted by this report. The walls are vertical planks of differing widths ..." (Gardner 1975:209-210). Gardner (1975) concluded that "The hand hewn timbers and their unique craftsmanship in constructing the frame, plus the sandstone slab walls" made the barn one of the most "precious" buildings encountered in his study. Because few North West Mounted Police buildings are still extant, these standing structures are of major historical significance. Other structures related to The Leavings were dismantled and moved when the Oxley Ranch headquarters were moved six miles upstream (Beaver Creek location) (Claresholm History Book Club 1974) or succumbed to natural erosional processes. There is good potential for the identification of other structures, e.g. wells, in addition to the barracks and barn. As there are few written records pertaining to The Leavings complex, the archaeological data associated with The Leavings could contribute significantly to our understanding of the era of the North West Mounted Police and Bonanza Ranching and therefore are also of major historic significance.

Because of the presence of the Benton (Macleod Trail), Kountz' establishment, the Oxley Ranch, the North West Mounted Police Detachment, and the Stage Coach Relay Station, the general area on Willow Creek around The Leavings may also be expected to yield sites associated with these activities. Historic sites relating to establishments such as the more recently established ranches such as the Driftwood Ranch and the H. Maurushat Ranch, potentially occur within Site No. 1.

Sites relating to the whiskey trade, North West Mounted Police, and the early ranches may also be expected in Site No. 2, Pine Coulee. The Pine Coulee whiskey post, for example, was the scene of the first North West Mounted Police arrests when William

Bond, Harry "Kamoose" Taylor and three other traders were captured by a mounted patrol. Other whiskey posts can be expected in this area since many of these establishments were very crude and temporary, some reputedly being little more than "holes in the wall" from which liquor was dispensed.

The historical potential of Site No. 3, Willow Creek near Lane/Kuntz Creek, represents a data gap. However, because of its proximity to reservoir Site Nos. 1 and 2, sites relating to the whiskey trade, North West Mounted Police and early ranching may be expected. Historic homesteads and ranches were observed in this reservoir area during the overflight. These structures have not been identified and their significance relative to the local and provincial history has not been determined.

The Oxley Ranch Headquarters Site [Beaver Creek (Oxley) location] in Site No. 4, Pine Coulee/Willow Creek, is of major historical importance. It is located in the southeast quarter of Section 31, Township 13, Range 28, west of the 4th Meridian. Tatro (1974) described the site contents. "The buildings are on the edge of a wide meadow that terminates at the bank of Willow Creek on the south... The house has had a portion removed which is now intact in the yard of Mr. James Gordon...The remainder of this one-storey house still with some ornimentation [sic] is in very poor condition with rot in the logs, partially collapsed floors, fallen verandah, V joint lining falling off, etc. Restoration would be possible but costly and extensive. The other building on site is the bunk house; a very fine example of this element of ranch life, but also in poor condition. An ice house was removed from the back (or west) of this building and a few logs and other evidence of this is present. A few logs also remain of the barn. Another structure of interest is the stone-lined well which in reality is a shaft down to a spring. A large stream about eight feet below surface runs in on the north and out on the south and continues a few yards underground then empties into Willow Creek." Because of its historical association with the original site of The Leavings and with the ranching industry, this site is of major historical significance. In this context, Tatro (1974) indicated that this site warrants careful evaluation as a National Historic Park (Tatro 1974).

Because Site No. 4 is largely coterminous with Site No. 2, the historic potential of the Pine Coulee portion of the former is identical with the latter. Other sites related to ranching, the whiskey trade, and North West Mounted Police activities may be expected in the Willow Creek portion of Site No. 4. The presence of the Oxley Ranch Headquarters Site (Beaver Creek location) in the floodplain of Willow Creek adjacent to the limits of the full supply level significantly increases the historical sensitivity of the area.

7.9.3 Palaeontological Sites

All identified collecting localities are outside the reservoir areas. The lack of collecting localities does not, however, indicate that no sites exist within the reservoir areas. Rather, it reflects the limited number of individuals who have directed their attention to the palaeontological resources within the area. Exposures of the basal part of the Porcupine Hills Formation are rare along the east side of the Porcupine Hills. Therefore, the presence of outcrops along Willow Creek are important because they represent some of the best exposures of both the underlying Willow Creek Formation and the Porcupine Hills Formation.

Examination of areal photographs of Site No. 1, Willow Creek near Claresholm, suggests that there is good potential for palaeontological sites. Although there is no extensive outcrop or near outcrop (very thin veneer of colluvium) along the creek throughout the proposed reservoir area, substantial outcrops occur along the valley walls. The exposures range from about 1.5 to 25 metres in thickness and are present on both valley walls. The sections consist of alternating sandstones, siltstones, and shales. The individual sandstone beds generally range from one to two metres in thickness except in the upper reaches of the reservoir where individual sandstones may be twenty to twenty-five metres thick. Shales and siltstones units, up to several metres thick, were noted.

Site No. 2, Pine Coulee, has limited palaeontological potential. The slopes of the coulee are mostly covered with colluvium with sandstone units outcropping along the east side of the valley and as isolated occurrences in other areas.

The potential for palaeontological sites in Site No. 3, Willow Creek near Lane Creek/Kuntz Creek, is restricted to one major locality, at the east end of the proposed reservoir. Approximately fifty metres of alternating sandstones, siltstones, and shales are exposed along Willow Creek for about one kilometre. Sandstones range up to fifteen metres at this locality.

The portion of Site No. 4, Pine Coulee/Willow Creek, which is coterminous with Site No. 2 has limited palaeontological potential. However, the addition of the confluence of Willow Creek in Site No. 4 results in the inclusion of a large outcropping of the Porcupine Hills Formation. This site represents one of the largest outcrops of the Porcupine Hills Formation in the area.

7.10 RANKING OF RESERVOIRS FOR HISTORICAL RESOURCE POTENTIAL

The rank order of the potential reservoir locations is based on 1) the perceived sensitivity of the individual reservoirs for historical resources, 2) the perceived scale of impact, and

3) the perceived degree of impact. Site No. 1, Willow Creek near Claresholm, has been assigned Rank Order 1, i.e. the most sensitive for existing and potential historical resources. It has a demonstrated high potential for prehistoric sites, historic sites, and palaeontological sites. Twenty-nine prehistoric sites occur within the F.S.L. ranging from simple isolated finds to composite bison kill complexes. The demonstrated high prehistoric site potential was derived from an essentially cursory field examination of the reservoir area in which no subsurface investigations were conducted to identify sites. It is expected that detailed studies will reveal the presence of many additional sites. The sensitivity of the Site No. 1, is increased by the presence of the historic Leavings site complex. This site represents two themes, Ranching and North West Mounted Police, characteristic of the history of southwestern Alberta. Standing structures on their original sites relating to the North West Mounted Police are rare. These structures in The Leavings site complex, as well as other features and associated archaeological remains are of major historical significance and warrant preservation. In addition, some of the best palaeontological exposures of both the underlying Willow Creek Formation and the Porcupine Hills Formation occur in this potential reservoir. As a result, it has the greatest potential for elucidating problems of stratigraphic correlation. The combined potential of the prehistorical, historical, and palaeontological sites make this reservoir the most sensitive with respect to historical resources.

Sites No. 2 and 3 are difficult to rank as to historical resource potential impact of development because of the lack of recorded historic and prehistoric sites within the F.S.L. With respect to Site No. 2, Pine Coulee, an inventory would be necessary, particularly to determine the nature and potential for deeply buried prehistoric sites. Pine Coulee was noted for harbouring illegal whiskey traders frequently pursued by the North West Mounted Police. Significant sites relating to this fascinating theme of southern Alberta may exist in this reservoir as well as sites relating to the Ranching Theme. Although Pine Coulee would appear to have limited potential for palaeontological resources because of the limited occurrence of outcrops, core holes drilled in this reservoir could penetrate the Porcupine Hills Formation into the underlying Willow Creek Formation and provide important stratigraphic data otherwise unavailable. Pine Coulee is ranked low for palaeontological potential/significance, low to medium for historic potential/significance, and reasonably high for prehistoric potential/significance.

Site No. 3, Willow Creek near Lane Creek/Kuntz Creek, would appear to have a reasonably high prehistoric site potential similar to that of Site No. 1 because it represents a continuation of a restricted settlement/activity corridor along the creek valley into the Porcupine Hills. Although no previously recorded historic sites are known in Site No. 3, during the overflight a number of structures and structural remains were observed. On the basis of present data, the significance of historic sites in this potential reservoir would rank low in comparison with reservoir Site Nos. 1 and 2. With the exception of the proposed dam site, limited bedrock exposures occur within Site No. 3. Site No. 3 is ranked lower than Site No. 1 but higher than Site No. 2 for palaeontological potential/significance.

Site No. 4, Pine Coulee/Willow Creek, ranks lower than Site No. 1 but higher than Site Nos. 2 and 3. The historic, prehistoric, and palaeontological potential of that portion of Site No. 4 which is coterminous with Site No. 2 is identical to that of the latter site. However, the addition of the confluence area of Willow Creek in Site No. 4 changes the sensitivity rating of this potential reservoir site. The presence of the large outcrop of Porcupine Hills Formation, the Oxley Ranch Headquarters Site (Beaver Creek location), and terrain, similar to that in Site No. 1, suitable for a number of prehistoric activities significantly raises the historical resource potential of Site No. 4.

Relative to the perceived scale of impact to significant sites within the F.S.L., because of the extent of the proposed development impact will occur on all three levels, site, local, and regional data. The degree of impact will be major at the site level in all four reservoirs. Assuming that comparable prehistoric sites exist outside of the F.S.L, impact at the local level can be minor to moderate. For example, impact to individual tipi rings may be major but if numerous such sites exist, limited mitigation can reduce impact to an acceptable level. Impact at the regional level is expected to be minor to moderate, based on the known distribution of prehistoric sites in Site Nos. 1 and 3. Development of Site No. 2, Pine Coulee, or Site No. 4, Pine Coulee/Willow Creek, because Pine Coulee is a relatively unique valley having potential for deeply buried old sites, could result in major impact to the regional data base if such sites exist. Should such sites, however, be sufficiently buried by colluvial and alluvial deposits, no impact would occur.

In Site No. 1, the historic Leavings Site complex is unique. Major impact will occur on the site level and will affect the local and regional history and interpretive potential. Low to medium impact will occur on the local and regional data in Site Nos. 2 and 3. Major impact could occur on the site level at the Oxley Ranch Headquarters Site (Beaver Creek location) situated in Site No. 4, Pine Coulee/Willow Creek, and could affect the local and regional history and interpretive potential of historic sites in the region.

With respect to palaeontological sites, impact will be major at Site No. 1, Willow Creek near Claresholm, and Site No. 4, Pine Coulee/Willow Creek, and minor at Site Nos. 2 and 3.

7.11 RECOMMENDED HISTORICAL RESOURCES IMPACT ASSESSMENT

7.11.1 Site No. 1, Willow Creek near Claresholm

A major historical resources impact assessment is required at this reservoir site if it is selected for development. The study components should include the following:

1. relocation and detailed mapping of all previously identified sites within the F.S.L.

2. a systematic ground reconnaissance of the entire zone within the F.S.L. prehistoric sites including subsurface testing (backhoe) for deeply buried sites; examination of bedrock exposures for pictographs, burial remains, and whiskey trade related activities;

3. major on-site examination of The Leavings site complex including mapping of the Macleod Trail, extant structures/features, archaeological remains;

4. documentation and identification of all historic structures/features;

5. a major historical program including archival research and informant interviews;

6. examination of cores from geotechnical drill-holes. Exposures are generally poor at the contact between the Willow Creek and the Porcupine Hills formations along the eastern side of the Porcupine Hills. Cores are potentially important for stratigraphic and biostratigraphic studies

should they penetrate from the Porcupine Hills formation into the underlying Willow Creek formation;

7. detailed geological studies including stratigraphy, sedimentology, and palaeontology (particularly palynology). Palynological studies of the cores are recommended for stratigraphic purposes because recovery of fossils of this type is more assured than other types;
8. examination of all outcrops for vertebrate fossils and collection of representative samples for palynological study;
9. collection of lithological samples and measurement of sections with permanent record filed with the Tyrrell Museum of Palaeontology;
10. development and utilization of a significance scheme relevant to the data base within the F.S.L. which incorporates scientific, local, and public aspects of site potential;
11. determination of impact to each of the historical resource sites identified with respect to the development plans;
12. a detailed assessment of all identified sites;
13. detailed recommendations for the development of a historical resources management plan including recommendations for appropriate site mitigation;
14. preparation of a publishable quality report on the findings.

7.11.2 Site No. 2, Pine Coulee

A major historical resources impact assessment is required at this reservoir site if it is selected for development. The study components should include the following:

1. a systematic ground reconnaissance of the entire zone within the F.S.L. for prehistoric sites including subsurface testing (backhoe) for deeply buried sites; examination of bedrock exposures for pictographs and burial remains;

2. a geological study to assess the potential of different areas of the reservoir to yield deeply buried archaeological material;

3. documentation and identification of all historic structures/features particularly whiskey trade related activities;

4. examination of cores from geotechnical drill-holes. Exposures are generally poor at the contact between the Willow Creek and the Porcupine Hills formations along the eastern side of the Porcupine Hills. Cores are potentially important for stratigraphic and biostratigraphic studies should they penetrate from the Porcupine Hills Formation into the underlying Willow Creek Formation;

5. detailed geological studies including stratigraphy, sedimentology, and palaeontology (particularly palynology). Palynological studies of the cores are recommended for stratigraphic purposes because recovery of fossils of this type is more assured than other types;

6. examination of all outcrops for vertebrate fossils and collection of representative samples for palynological study;

7. collection of lithological samples and measurement of sections with permanent record filed with the Tyrrell Museum of Palaeontology;

8. development and utilization of a significance scheme relevant to the data base within the F.S.L. which incorporates scientific, local, and public aspects of site potential;

9. determination of impact to each of the historical resource sites identified with respect to the development plans;

10. detailed assessment of all identified sites;

11. detailed recommendations for the development of a historical resources management plan including recommendations for appropriate site mitigation;

12. preparation of a publishable quality report on the findings.

7.11.3 Site No. 3, Willow Creek, near Lane Creek/Kuntz Creek

A major historical resources impact assessment is required at this reservoir site if it is selected for development. The study components should include the following:

1. a systematic ground reconnaissance of the entire zone within the F.S.L. for prehistoric sites including subsurface testing (backhoe) for deeply buried sites; examination of bedrock exposures for pictographs and burial remains;

2. documentation and identification of all historic structures/features;

3. detailed geological studies including stratigraphy, sedimentology, and palaeontology (particularly palynology);

4. examination of all outcrops for vertebrate fossils and collection of representative samples for palynological study;

5. collection of lithological samples and measurement of sections with permanent record filed with the Tyrrell Museum of Palaeontology;

6. development and utilization of a significance scheme relevant to the data base within the F.S.L. which incorporates scientific, local, and public aspects of site potential;

7. determination of impact to each of the historical resource sites identified with respect to the development plans;

8. detailed assessment of all identified sites;

9. detailed recommendations for the development of a historical resources management plan including recommendations as to appropriate site mitigation;

10. preparation of a publishable quality report on the findings.

7.11.4 Site No. 4, Pine Coulee/Willow Creek

A major historical resources impact assessment is required at this reservoir site if it is selected for development. The study components should include the following:

1. a systematic ground reconnaissance of the entire zone within the F.S.L. for prehistoric sites including subsurface testing (backhoe) for deeply buried sites; examination of bedrock exposures for pictographs and burial remains;

2. major on-site examination of the Oxley Ranch Headquarters Site (Beaver Creek location) including mapping of the extant structures/features, archaeological remains;

3. documentation and identification of all historic structures/features;

4. a geological study to assess the potential of different areas of the reservoir to yield deeply buried archaeological material;

5. documentation and identification of all historic structures/features particularly whiskey trade related activities;

6. examination of cores from geotechnical drill-holes. Exposures are generally poor at the contact between the Willow Creek and the Porcupine Hills formations along the eastern side of the Porcupine Hills. Cores are potentially important for stratigraphic and biostratigraphic studies should they penetrate from the Porcupine Hills Formation into the underlying Willow Creek Formation;

7. detailed geological studies including stratigraphy, sedimentology, and palaeontology (particularly palynology). Palynological studies of the cores are recommended for stratigraphic purposes because recovery of fossils of this type is more assured than other types;

8. examination of all outcrops for vertebrate fossils and collection of representative samples for palynological study;
9. collection of lithological samples and measurement of sections with permanent record filed with the Tyrrell Museum of Palaeontology;
10. development and utilization of a significance scheme relevant to the data base within the F.S.L. which incorporates scientific, local, and public aspects of site potential;
11. determination of impact to each of the historical resource sites identified with respect to the development plans;
12. detailed assessment of all identified sites;
13. detailed recommendations for the development of a historical resources management plan including recommendations for appropriate site mitigation;
14. preparation of a publishable quality report on the findings.

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8.0 WATER QUALITY

8.1 COMPONENT REQUIREMENTS

This section of the report overviews historic surface water quality conditions in the Willow Creek Basin and identifies the major controlling variables. It emphasizes interpretation of existing data and relies on similar studies carried out elsewhere in southern Alberta. The water quality and limnologic characteristics of four potential reservoir storage sites are also considered. Specific objectives include the following;

1. With existing data, define open-water season water quality patterns, including changes in quality with downstream distance along Willow Creek and season.

2. Compare historical water quality with specific use objectives for domestic supply, irrigation, fisheries, recreation and livestock watering. Relate water quality to Alberta Surface Water Objectives.

3. Identify significant water quality impact sources, i.e., municipal discharges, feedlots, saline seeps, etc. Define the degree and timing of impacts relative to season and streamflow conditions. Define optimum periods for water withdrawal for domestic supply. Discuss the implications of each of the reservoir locations in terms of influence on water quality.

4. If possible, identify patterns in nuisance weed and algal growth and any impacts they have on irrigation.

8.2 METHODS

Multiple source (Table 8-1) water quality data were compiled into a single datafile and installed on ROSCOE. Although more data were available this compilation was restricted to seven locations spaced longitudinally through the basin (Table 8-2), and includes only data collected after 1970. The data at intervening sites were either sporadic in frequency or incomplete for parameters. Except for nitrate and manganese the data were edited to ensure continuity of analytical detection limits. The manganese and nitrate detection limits varied so often that uniformity in the dataset could not be achieved without drastically reducing the sample size. To provide a sufficient sample size for the upper reaches, data from the three upstream Pine Coulee sites were combined. SPSSX was used for all statistical analyses (SPSS INC., 1983).

Water Survey of Canada daily average discharge data for sites near Claresholm and at HWY 2 were incorporated into the historic water quality dataset. Due to their close proximity, HWY 2 discharge values were also applied to the Hwy 811 water quality dataset. It is recognized that due to intervening irrigation withdrawal actual summer flows between these two locations may vary.

The use specific water quality objectives applied to the South Saskatchewan River Basin Planning Program were tested against the Willow Creek dataset (Hamilton, 1982). The objectives for contact recreation were updated according to the recently published national guidelines (Health & Welfare Canada, 1983).

TABLE 8-1 WATER QUALITY DATA SOURCES

AGENCY	PERIOD	SITES
ENVIRONMENT CANADA	1971-1974	CLARESHOLM/HWY. 2
MOUNT ROYAL COLLEGE	1983	NEAR CHAIN LAKES/CLARESHOLM/ HWY. 811
MUNICIPAL ENGINEERING BR./ ALBERTA ENVIRONMENT	1970-1983	CLARESHOLM WATER SUPPLY DATA
ALBERTA ENVIRONMENTAL CENTRE	1983-1984	HWY. 2
WATER QUALITY CONTROL BR./ ALBERTA ENVIRONMENT	1978,1984	HWY. 811
FISH & WILDLIFE DIVISION/ ENERGY & NATURAL RESOURCES	1981	NEAR LANE CREEK/GRANUM/CLARESHOLM/ HWY 811.
STANDARDS & APPROVALS DIVN./ ALBERTA ENVIRONMENT	1977,1978, 1980,1982	PROVINCIAL PARK/CLARESHOLM/GRANUM/ HWY 2/HWY 811

TABLE 8-2 SITES SELECTED FOR WATER QUALITY DATA ANALYSIS

D/S CHAIN LAKES	-	BRIDGE ON STAVELY ROAD, 2.3KM FROM ROADWAY #533
D/S LANE CREEK	-	AT CONFLUENCE OF LANE CREEK WITH WILLOW CREEK
WILLOW CREEK PROVINCIAL PARK	-	AT PARK JUST UPSTREAM OF PINE COULEE
CLARESHOLM	-	ROADWAY #520 BRIDGE
GRANNUM	-	CREEK CROSSING WEST OF GRANUM
HWY. 2	-	HIGHWAY BRIDGE SOUTH OF GRANUM
HWY. 811	-	NORTH OF FORT MCLEOD

8.3 RESULTS AND DISCUSSION

8.3.1 Hydrology

Flow is perhaps the most important variable affecting stream water quality. An understanding of streamflow patterns is intrinsic to interpretation of water quality trends.

The surface water regime of Willow Creek is dominated by snowmelt runoff, which peaks in June (Table 8-3) (Klohn Leonoff, 1984). Winter low flows start rising in March and April as snowmelt occurs in the lower foothills and plains portion of the basin. Upper foothill and mountain melt sustains the rising hydrograph into June. Flows tend to decrease rapidly during July, so that late summer and fall flows are naturally low ($<2m^3$/sec). Lower basin flows are to some extent regulated by Chain Lakes.

8.3.2 Trends in Willow Creek Water Quality

Analysis of the historic water quality database indicates best conditions occur in the reach between Chain Lakes and Claresholm. Downstream of Claresholm ground-water inflow and agricultural activities affect stream quality. Many parameters are season and streamflow dependant. Table 8-4 summarizes the combined Willow Creek water quality database by site and season. Early openwater refers to the months of April through end of July, the late openwater season includes August through November.

8.3.2.1 Major Ions

Salinity of water is a function of its major ion chemistry. Total dissolved solids (TDS) is a direct measure of salt content, while electrical conductivity is an indirect indicator. For any given stream the two parameters are usually highly correlated unless the major ion composition varies greatly over time or between sites. There are few TDS data for Willow Creek, however, the conductivity record is substantial.

TABLE 8-3 MEAN MONTHLY DISCHARGE OF WILLOW CREEK(m^3/sec)

	J	F	M	A	M	J	J	A	S	O	N	D
NEAR CLARESHOLM	0.45	0.67	2.29	5.14	10.1	11.0	4.55	1.78	1.45	1.30	0.86	0.58
NEAR NOLAN(HWY.2)	0.40	0.68	3.27	6.65	12.9	16.2	7.13	2.98	2.40	2.03	1.46	0.80

TABLE 8-4 SUMMARY WATER QUALITY STATISTICS FOR WILLOW CREEK SITES (1970-1984)

STEM	PERIOD	CONDUCT. US/CM	TDS MG/L	PH PH UNITS	ALKALIN MG/L	HARDNESS MG/L	CALCIUM MG/L	MAGNESIUM MG/L	SODIUM MG/L	POTASSIUM MG/L
U/S PINE C	EARLY OPEN									
	MEAN	362	.	8.5	.	193	47	16	15	2
	CASES	18	0	18	0	4	4	4	18	4
	LATE OPEN									
	MEAN	405	.	8.3	.	202	44	22	17	3
	CASES	6	0	6	0	3	3	3	5	3
	TOTAL MEAN	373	.	8.4	.	197	46	19	15	3
	MIN	280	.	7.9	.	156	35	11	7	2
	MAX	470	.	8.7	.	225	53	25	25	3
	90%	420	.	8.7	.	.	.	.	22	.
CLARESHOLM	EARLY OPEN									
	MEAN	363	.	8.4	.	184	.	.	16	3
	CASES	19	0	19	0	4	0	0	18	4
	LATE OPEN									
	MEAN	403	.	8.4	206	189	59	10	19	3
	CASES	9	0	9	2	5	2	2	7	5
	TOTAL MEAN	376	.	8.4	206	187	59	10	17	3
	MIN	250	.	8.0	190	172	53	3	6	2
	MAX	470	.	8.8	222	210	64	17	25	4
	90%	445	.	8.6	.	210	.	.	25	4
GRANUM	EARLY OPEN									
	MEAN	426	264	8.4	179	189	42	20	21	3
	CASES	17	5	17	5	9	9	9	17	9
	LATE OPEN									
	MEAN	465	270	8.4	198	186	34	25	32	3
	CASES	10	6	10	6	9	9	9	9	9
	TOTAL MEAN	440	267	8.4	189	188	38	22	25	3
	MIN	310	237	7.3	134	114	11	15	9	2
	MAX	530	291	9.2	288	220	50	28	46	5
	90%	505	290	8.7	277	212	50	27	43	4
HWY 2	EARLY OPEN									
	MEAN	395	240	8.6	189	166	43	16	27	3
	CASES	15	1	15	2	1	2	1	14	2
	LATE OPEN									
	MEAN	470	347	8.6	201	194	31	31	45	3
	CASES	7	2	7	4	2	4	2	5	4
	TOTAL MEAN	419	311	8.6	197	185	35	26	32	3
	MIN	260	213	8.0	150	166	13	15	11	3
	MAX	722	481	9.7	227	213	51	38	102	4
	90%	479	.	9.2	.	.	.	.	5.5	.
HWY 811	EARLY OPEN									
	MEAN	446	306	8.4	214	164	35	21	30	3
	CASES	30	13	30	12	12	16	16	30	16
	LATE OPEN									
	MEAN	471	361	8.4	227	184	33	25	34	3
	CASES	16	7	16	9	4	12	12	15	12
	TOTAL MEAN	455	325	8.4	219	169	34	23	31	3
	MIN	310	249	7.4	176	75	15	9	9	2
	MAX	642	441	8.8	324	212	55	29	66	4
	90%	517	430	8.6	287	209	47	29	52	4

TABLE 8-4 CONTINUED

STEM	PERIOD	HCO3 MG/L	SULFATE MG/L	CHLORIDE MG/L	TEMP DEG C	OXYGEN MG/L	SAR REL UNITS	DISCHARGE M3/SEC
U/S PINE C	EARLY OPEN							
	MEAN	222	25	1.6	12.5	9.6	.3	.
	CASES	4	18	6	6	6	4	0
	LATE OPEN							
	MEAN	252	24	3.6	12.8	9.0	.5	.
	CASES	3	6	4	4	3	3	0
	TOTAL MEAN	235	25	2.4	12.6	9.4	.4	.
	MIN	177	12	.5	1.0	7.4	.2	.
	MAX	263	48	10.6	18.0	13.0	.6	.
	90%	.	35	9.7	18.0	13.0	.	.
CLARESHOLM	EARLY OPEN							
	MEAN	225	29	2.1	13.8	8.6	.	6.57
	CASES	4	18	6	6	5	0	20
	LATE OPEN							
	MEAN	252	29	2.0	15.5	9.0	.5	1.69
	CASES	5	8	6	4	3	2	8
	TOTAL MEAN	240	29	2.1	14.5	8.7	.5	5.18
	MIN	195	14	.7	3.0	7.0	.5	.13
	MAX	278	62	4.0	24.0	10.2	.5	37.30
	90%	287	43	3.8	23.6	.	.	16.10
GRANUM	EARLY OPEN							
	MEAN	214	44	2.8	13.2	8.7	.6	.
	CASES	9	17	9	4	3	9	0
	LATE OPEN							
	MEAN	242	47	3.4	13.2	8.8	.9	.
	CASES	9	10	9	3	2	9	0
	TOTAL MEAN	228	45	3.1	13.2	8.8	.7	.
	MIN	159	19	.2	5.0	8.4	.2	.
	MAX	291	102	7.0	20.0	9.0	1.7	.
	90%	271	89	5.5	89	.	1.4	.
HWY 2	EARLY OPEN							
	MEAN	.	41	1.5	18.1	.	.5	6.91
	CASES	0	14	2	4	0	1	18
	LATE OPEN							
	MEAN	.	67	3.1	12.0	10.3	2.0	3.03
	CASES	0	6	4	3	1	2	7
	TOTAL MEAN	.	49	2.6	15.5	10.3	1.5	5.82
	MIN	.	22	1.1	7.0	10.3	.5	.01
	MAX	.	181	7.0	24.4	10.3	3.0	33.40
	90%	.	62	.	.	.	.	23.4
HWY 811	EARLY OPEN							
	MEAN	242	42	2.4	14.8	10.1	.9	5.61
	CASES	12	30	17	18	12	16	30
	LATE OPEN							
	MEAN	250	51	3.3	14.2	9.0	.9	2.21
	CASES	5	16	14	12	4	12	16
	TOTAL MEAN	244	45	2.8	14.5	9.8	.9	4.43
	MIN	212	10	.9	4.0	6.2	.3	.01
	MAX	286	136	7.1	26.1	12.9	2.1	47.50
	90%	283	63	5.8	20.4	12.8	1.6	11.16

TABLE 8-4 CONTINUED

STEN	PERIOD	PHENOL MG/L	DOC MG/L	POC MG/L	AMMONIA MG/L	NO2&NO3 MG/L	TKN MG/L	TP MG/L	DP MG/L	NFR MG/L	TURBIDITY MG/L
U/S PINE C	EARLY OPEN										
	MEAN	.	.	.	.290	.020	.	.015	.	4	26.2
	CASES	0	0	0	5	1	0	1	0	2	6
	LATE OPEN										
	MEAN	.	.	.	.090	.040	.	.012	.	3	1.5
	CASES	0	0	0	3	1	0	1	0	1	4
	TOTAL MEAN	.	.	.	.215	.030	.	.013	.	3	16.3
	MIN	.	.	.	.090	.020	.	.012	.	3	1.0
	MAX	.	.	.	.700	.040	.	.015	.	4	73.0
	90%	.	.	.	.	.	.	.	.	.	72
CLARESHOLM	EARLY OPEN										
	MEAN	.	.	.	.223	.	.	.021	.	12	20.5
	CASES	0	0	0	6	0	0	1	0	2	6
	LATE OPEN										
	MEAN	.	.	.	.090	.045	.49	.006	.	2	1.9
	CASES	0	0	0	3	2	2	2	0	1	6
	TOTAL MEAN	.	.	.	.179	.045	.49	.011	.	8	11.2
	MIN	.	.	.	.060	.010	.49	.004	.	2	1.0
	MAX	.	.	.	.900	.080	.49	.021	.	14	85.0
	90%	.	.	.	.09	.	.	.		.	66
GRANUM	EARLY OPEN										
	MEAN	.	.	.	.497	.049	.	.	.	.	48.8
	CASES	0	0	0	4	6	0	0	0	0	4
	LATE OPEN										
	MEAN	.	.	.	.090	.063	.	.	.	.	2.0
	CASES	0	0	0	3	6	0	0	0	0	3
	TOTAL MEAN	.	.	.	.323	.056	.	.	.	.	28.7
	MIN	.	.	.	.090	.049	.	.	.	.	1.0
	MAX	.	.	.	1.400	.090	.	.	.	.	150.0
	90%	.	.	.	.	.	.	.	.	.	.
HWY 2	EARLY OPEN										
	MEAN	.	7.5	.	.	.072	.48	.240	.	56	170.0
	CASES	0	1	0	0	2	1	2	0	1	1
	LATE OPEN										
	MEAN	.002	8.8	.	.018	.014	.78	.009	.	3	3.1
	CASES	1	2	0	2	4	2	4	0	2	2
	TOTAL MEAN	.002	8.4	.	.018	.033	.68	.086	.	24	58.7
	MIN	.002	4.2	.	.004	.002	.32	.006	.	5	1.6
	MAX	.002	13.5	.	.032	.075	1.24	.420	.	56	170.0
	90%	.	.	.	.		.	.	.	.	.
HWY 811	EARLY OPEN										
	MEAN	.003	3.3	.83	.172	.046	.47	.141	.013	9	14.9
	CASES	9	6	5	12	17	2	14	10	10	14
	LATE OPEN										
	MEAN	.002	5.8	.46	.106	.035	.64	.020	.009	7	2.8
	CASES	2	2	1	7	13	1	10	9	4	6
	TOTAL MEAN	.003	4.0	.77	.148	.041	.53	.091	.011	8	11.2
	MIN	.002	2.2	.43	.006	.005	.45	.007	.003	3	.8
	MAX	.004	8.2	1.27	1.000	.120	.64	1.200	.040	14	130.0
	90%	.004	.	.	.310	.090	.	.175	.020	14	38

TABLE 8-4 CONTINUED

STEM	PERIOD	COLOR REL UNITS	TOT COLIF NO./100ML	FEC COLIF NO./100ML	DISCHARGE M3/SEC
U/S PINE C	EARLY OPEN				
	MEAN	15	81	55	.
	CASES	2	11	10	0
	LATE OPEN				
	MEAN	15	42	34	.
	CASES	1	3	3	0
	TOTAL MEAN	15	70	49	.
	MIN	10	2	16	.
	MAX	20	540	240	.
	90%	.	420	240	.
CLARESHOLM	EARLY OPEN				
	MEAN	45	103	57	6.08
	CASES	2	10	10	15
	LATE OPEN				
	MEAN	12	21	22	1.33
	CASES	3	3	2	8
	TOTAL MEAN	25	71	49	4.43
	MIN	5	4	2	.01
	MAX	80	920	350	37.30
	90%	.	792	344	13.9
GRANUM	EARLY OPEN				
	MEAN	.	71	26	.
	CASES	0	9	9	0
	LATE OPEN				
	MEAN	.	9	9	.
	CASES	0	2	2	0
	TOTAL MEAN	.	49	22	.
	MIN	.	2	2	.
	MAX	.	1600	540	.
	90%	.	1388	502	.
HWY 2	EARLY OPEN				
	MEAN	.	117	57	7.81
	CASES	0	9	9	11
	LATE OPEN				
	MEAN	9	19	19	3.06
	CASES	2	2	2	6
	TOTAL MEAN	9	84	47	6.14
	MIN	8	4	4	.11
	MAX	10	2400	2400	33.40
	90%	.	2240	2028	26.3
HWY 811	EARLY OPEN				
	MEAN	13	68	31	5.97
	CASES	2	18	18	27
	LATE OPEN				
	MEAN	30	148	13	2.23
	CASES	2	4	4	16
	TOTAL MEAN	21	78	27	4.58
	MIN	10	9	1	.03
	MAX	30	500	198	47.50
	90%	.	487	170	11.5

TABLE 8-4 CONTINUED

STEM	PERIOD	AS MG/L	BA MG/L	BO MG/L	CU MG/L	PB MG/L	FE MG/L	MN MG/L	SI MG/L	ZN MG/L
U/S PINE C	EARLY OPEN									
	MEAN	.	.	.	.	.	1.22	.02	.	.
	CASES	0	0	0	0	0	6	2	0	0
	LATE OPEN									
	MEAN	.	.	.	.	.	.11	.02	.	.
	CASES	0	0	0	0	0	4	1	0	0
	TOTAL MEAN	.	.	.	.	.	.78	.02	.	.
	MIN	.	.	.	.	.	.06	.02	.	.
	MAX	.	.	.	.	.	3.700	.02	.	.
	90%	.	.	.	.	.	3.58	.		
CLARESHOLM	EARLY OPEN									
	MEAN	.006	.17	.06	.007	.002	1.25	.07	.009	.
	CASES	3	3	1	3	3	9	5	3	0
	LATE OPEN									
	MEAN	.005	.10	.03	.001	.001	.10	.01	.009	.006
	CASES	1	3	2	3	3	7	4	3	2
	TOTAL MEAN	.006	.13	.04	.004	.001	.75	.04	.009	.006
	MIN	.005	.09	.02	.001	.001	.07	.01	.009	.003
	MAX	.008	.30	.06	.016	.004	4.600	.26	.009	.010
	90%	.	.	.	.	.	4.50	.26	.	.
GRANUM	EARLY OPEN									
	MEAN	.	.	.	.	.	1.24	.12	.	.
	CASES	0	0	0	0	0	4	4	0	0
	LATE OPEN									
	MEAN	.	.	.	.	.	.15	.08	.	.
	CASES	0	0	0	0	0	3	3	0	0
	TOTAL MEAN	.	.	.	.	.	.77	.10	.	.
	MIN	.	.	.	.	.	.10	.05	.	.
	MAX	.	.	.	.	.	3.900	.20	.	.
	90%	.	.	.	.	.	.	.		
HWY 2	EARLY OPEN									
	MEAN	.006	.20	.08	.006	.002	2.90	.13	.009	.011
	CASES	4	5	2	6	6	6	6	5	5
	LATE OPEN									
	MEAN	.005	.13	.03	.001	.003	.12	.01	.009	.002
	CASES	1	3	2	5	5	5	5	2	4
	TOTAL MEAN	.006	.17	.06	.004	.002	1.64	.08	.009	.007
	MIN	.005	.09	.02	.001	.001	.10	.01	.009	.001
	MAX	.008	.40	.10	.014	.007	7.600	.36	.009	.017
	90%	.	.	.	.014	.007	7.56	.354	.	0.17
HWY 811	EARLY OPEN									
	MEAN	.	.	.	.	.	.49	.08	.	.
	CASES	0	0	0	0	0	14	6	0	0
	LATE OPEN									
	MEAN	.	.	.	.	.	.12	.06	.	.
	CASES	0	0	0	0	0	6	5	0	0
	TOTAL MEAN	.	.	.	.	.	.38	.07	.	.
	MIN	.	.	.	.	.	.03	.02	.	.
	MAX	.	.	.	.	.	4.200	.20	.	.
	90%	.	.	.	.	.	1.29	.178	.	.

TABLE 8-4 CONTINUED

STEM	PERIOD	CD	HG	CR	NI	DISCHARGE
		MG/L	UG/L	MG/L	MG/L	MG/L
U/S PINE C	EARLY OPEN					
	MEAN	.	.	.	.	.
	CASES	0	0	0	0	0
	LATE OPEN					
	MEAN	.	.	.	.	.
	CASES	0	0	0	0	0
	TOTAL MEAN	.	.	.	.	.
	MIN	.	.	.	.	.
	MAX	.	.	.	.	.
	90%	.	.	.	.	.
CLARESHOLM	EARLY OPEN					
	MEAN	.001	.049	.009	.014	9.42
	CASES	2	1	3	2	9
	LATE OPEN					
	MEAN	.001	.049	.009	.003	1.19
	CASES	3	2	3	3	7
	TOTAL MEAN	.001	.049	.009	.008	5.82
	MIN	.001	.049	.009	.001	.01
	MAX	.002	.049	.009	.024	37.30
	90%	.	.	.	.	24.14
GRANUM	EARLY OPEN					
	MEAN	.	.	.	.	.
	CASES	0	0	0	0	0
	LATE OPEN					
	MEAN	.	.	.	.	.
	CASES	0	0	0	0	0
	TOTAL MEAN	.	.	.	.	.
	MIN	.	.	.	.	.
	MAX	.	.	.	.	.
	90	.	.	.	.	.
HWY 2	EARLY OPEN					
	MEAN	.001	.049	.009	.010	10.89
	CASES	4	2	5	4	6
	LATE OPEN					
	MEAN	.001	.049	.009	.005	1.21
	CASES	5	2	4	5	5
	TOTAL MEAN	.001	.049	.009	.007	6.49
	MIN	.001	.049	.009	.001	.11
	MAX	.002	.049	.010	.017	33.40
	90%	.002	.	.010	.017	31.24
HWY 811	EARLY OPEN					
	MEAN	.	.	.	.	5.20
	CASES	0	0	0	0	14
	LATE OPEN					
	MEAN	.	.	.	.	.75
	CASES	0	0	0	0	6
	TOTAL MEAN	.	.	.	.	3.87
	MIN	.	.	.	.	.03
	MAX	.	.	.	.	47.50
	90%	.	.	.	.	13.81

Conductivities are similar at the U/S Pine Coulee and Claresholm sites (375 us/cm). Values increase at the lower basin sites to a maximum at HWY 811 (455 us/cm). Levels tend to be greater during the late versus early open water periods. Although streamflows are lower during the late season there is not a good inverse relationship between conductivity and discharge (Table 8-5). This may be a function of measurement error or lack of adequate flow dispersion across the dataset. A lower early open water mean conductivity at HWY 2 relative to HWY 811 likely reflects a greater proportion of high flow samples in the HWY 2 dataset. Average TDS and conductivity concentrations for Willow Creek near the mouth are higher than comparable Oldman River values (363 us/cm, 195 mg/l).

The cation dominance at the U/S Pine Coulee locations is Ca>Mg>Na>K. This switches to Ca>Na>Mg>K near the mouth. The upstream condition is typical of mountain runoff streams and major southern Alberta rivers. Magnesium and potassium concentrations remain static throughout the system, while calcium concentrations decline slightly with downstream distance. Summer biological activity can deplete inorganic carbon which inturn causes precipitation of calcium carbonate. A substantial increase in sodium content occurs between Claresholm and Granum, especially during the late open water interval. Magnesium and potassium concentrations remain seasonally constant, while calcium concentrations are greater in the early open water period when mountain runoff is high and plant growth minimal.

At all locations the anion dominance is HCO_3>>SO_4>>Cl. Total average bicarbonate concentrations vary little (235 to 244 mg/l), however, late summer concentrations are lower relative to the early season. Chloride levels remain between two and three mg/l throughout the basin. Like sodium, sulphate concentrations increase in the reach between Claresholm and HWY 2.

TABLE 8-5 CORRELATION ANALYSIS RESULTS BETWEEN DISCHARGE AND WATER QUALITY (LOG NORMAL DISTRIBUTIONS)

	CORRELATION COEFFICIENTS(r)	
PARAMETER	CLARESHOLM	HWY. 2 + HWY. 811
CONDUCTIVITY	-.34	-.25
SODIUM	-.82	-.72
SULPHATE	-.35	-.53
TOTAL COLIFORMS	ND	NS
FECAL COLIFORMS	ND	NS
NITRATE+NITRITE	ND	NS
AMMONIA	ND	0.39
TOTAL PHOSPHORUS	ND	0.35
TURBIDITY	0.53	0.52

(NS) NOT STATISTICALLY SIGNIFICANT AT P=0.05

ND INSUFFICIENT DATABASE

Sodium and sulphate concentrations are both inversely flow dependant (Figures 8-1 & 8-2). This reflects groundwater input which is characteristically high in $NaSO_4$. The maximum groundwater inflow to Willow Creek occurs between Claresholm and HWY 2. This input is most evident when surface runoff is low.

Water hardness is determined by the sum of calcium and magnesium ions and relates to domestic supply. Willow Creek water is classified as hard to very hard (McNeely et al, 1979). Alkalinity is a measure of buffering capacity. Average values between 189 and 219 mg/l indicate Willow Creek is a well buffered system.

8.3.2.2 Temperature

The longterm temperature record does not define detailed patterns because of its sporadic nature. Maximum recorded values do increase in a downstream direction, from 18°C upstream of Pine Coulee to greater than 26°C at HWY 811.

This longitudinal pattern is confirmed by the 1981 detailed thermograph record obtained by Fish and Wildlife Division, Department of Energy & Natural Resources (Figure 8-3). Peak temperatures occurred in August, along with maximum diurnal fluctuation. The daily maximum at Claresholm did not exceed 22°C, whereas at HWY 811 temperatures often approached 24°C, and exceeded 26°C.

8.3.2.3 Oxygen

Although data are limited, summer oxygen levels appear to remain near saturation throughout the system. This is in contrast to some southern Alberta streams where prolific weed and algal growth results in nighttime oxygen depletion. A potential problem area exists downstream from HWY 2, where the stream gradient is reduced. This promotes macrophyte production and limits atmospheric reaeration.

FIGURE 8-1 Relationship between discharge and sodium for HWY 2 and HWY 811

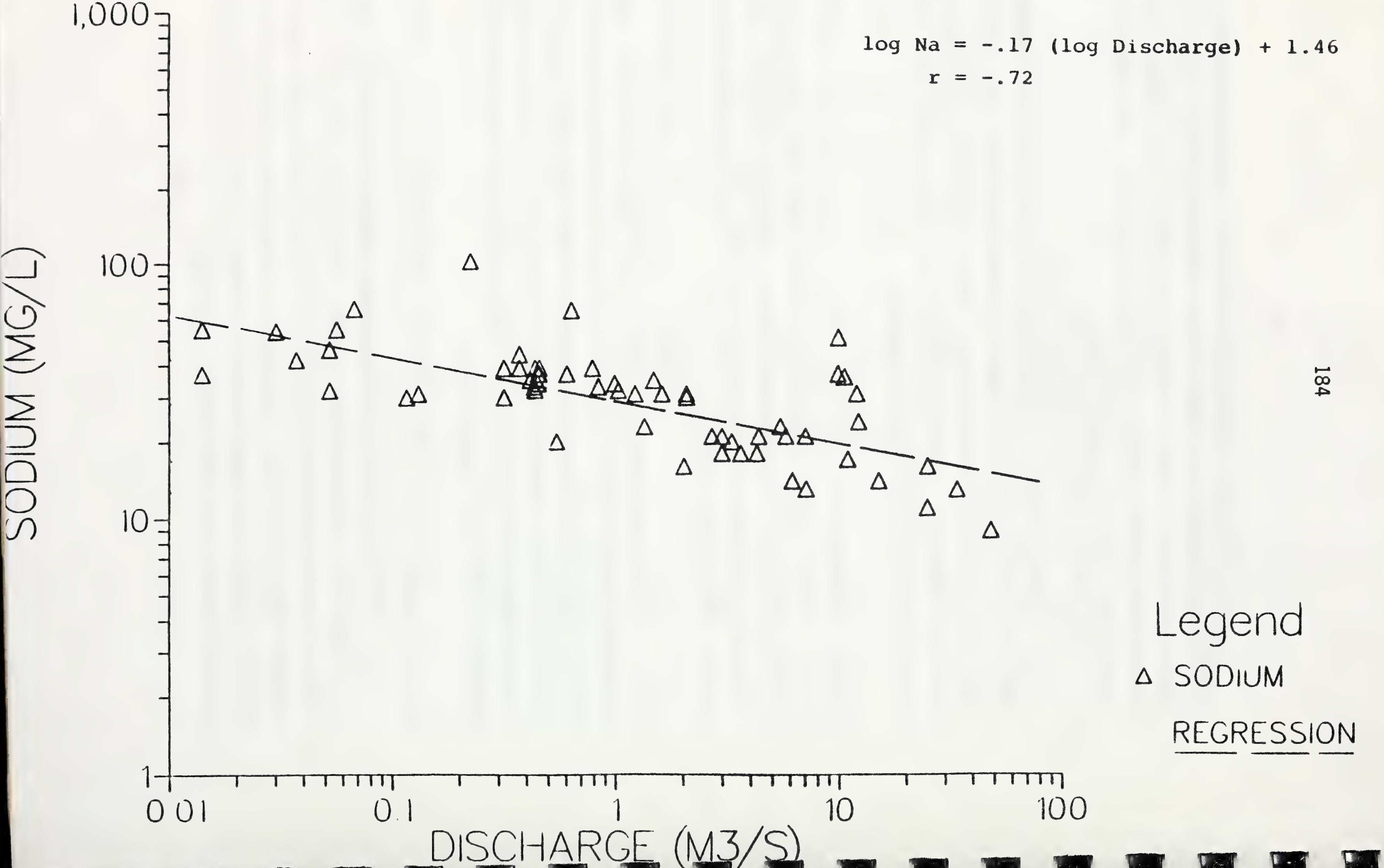


FIGURE 8-2 Relationship between discharge and sulphate for HWY 2 and HWY 811

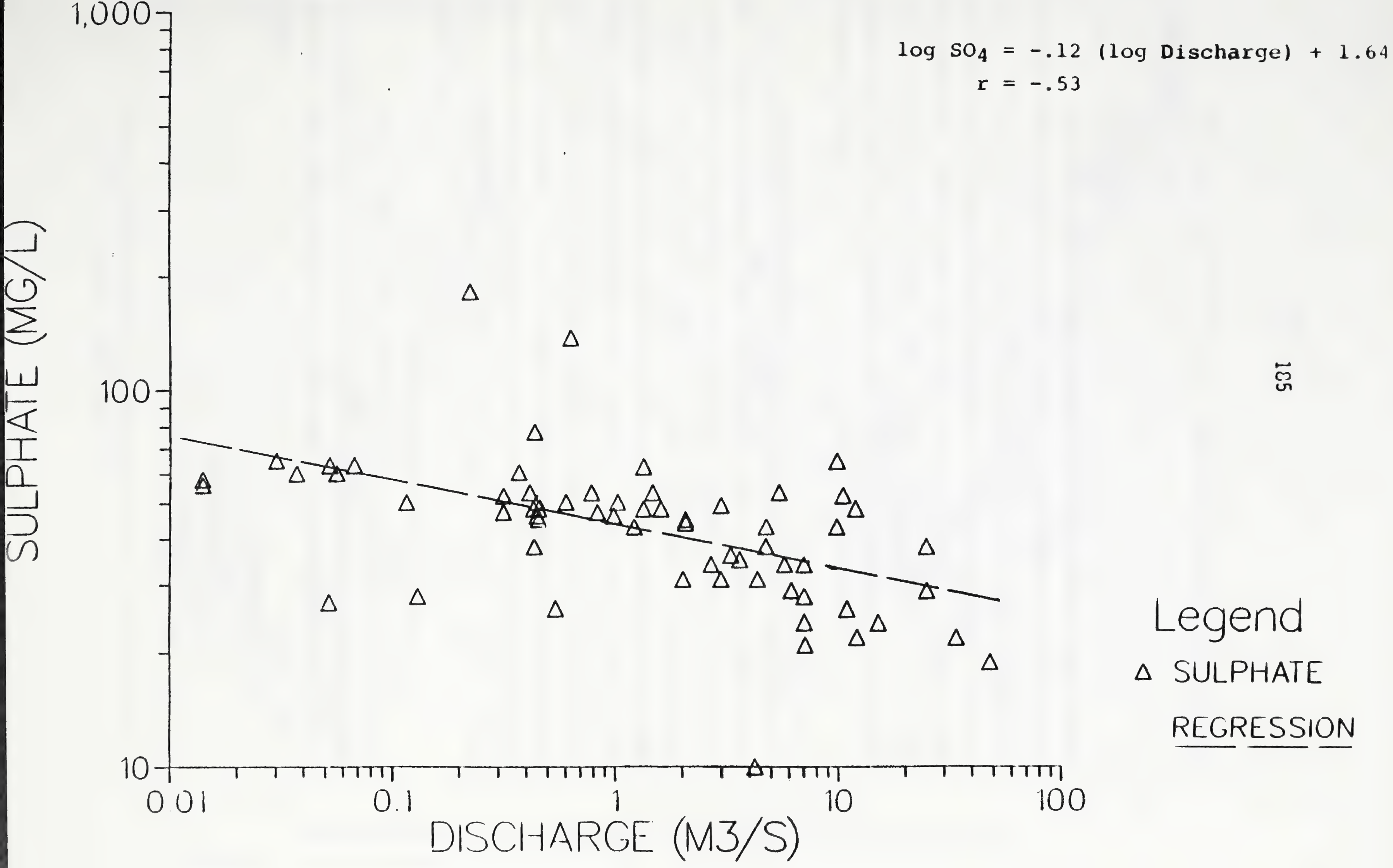
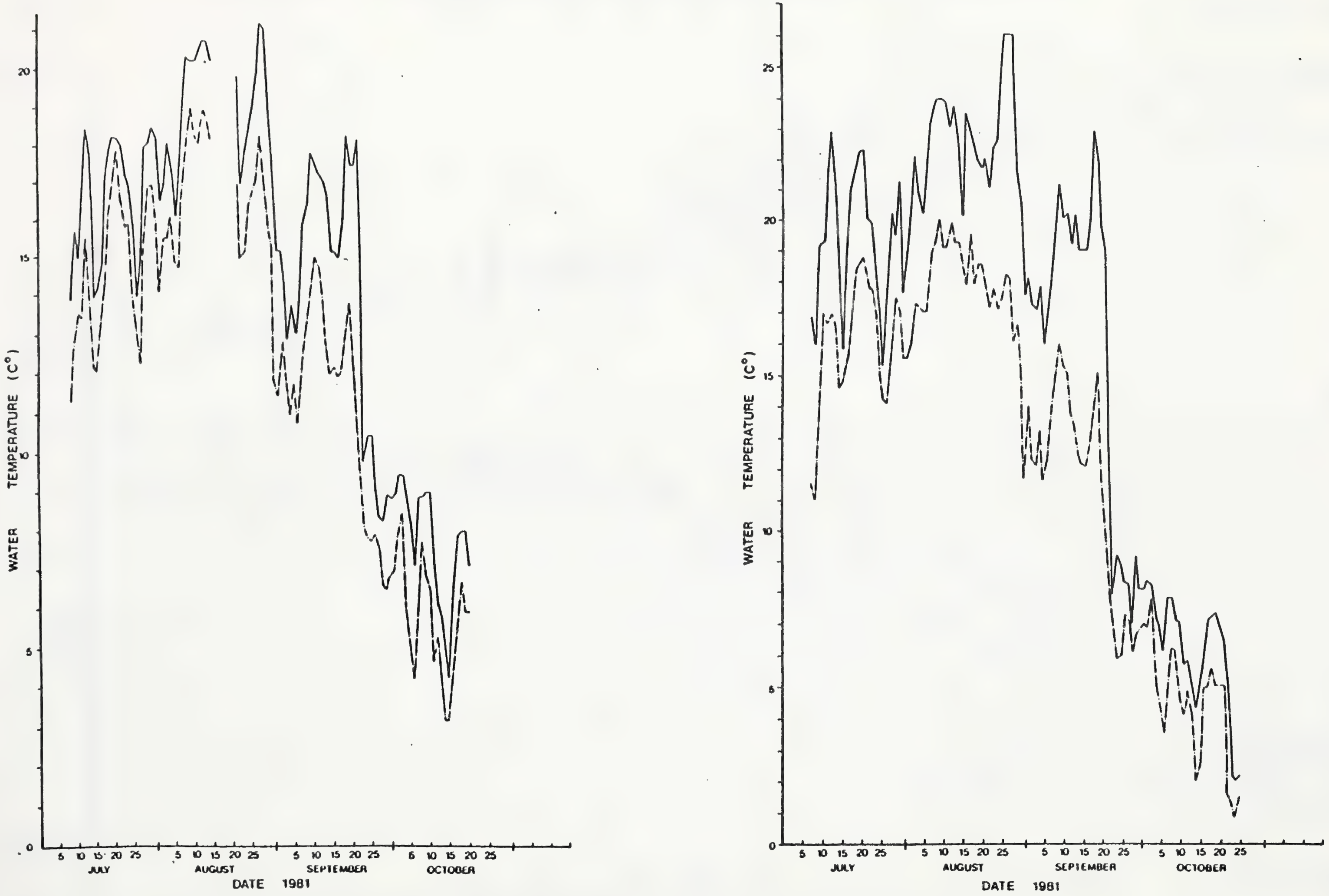


FIGURE 8-3 DAILY MINIMUM AND MAXIMUM WATER TEMPERATURES IN WILLOW CREEK, 1981
DATA PROVIDED BY FISH AND WILDLIFE DIVISION, ENR.



CLARESHOLM

HIGHWAY 811

There are insufficient data to assess Willow Creek winter oxygen conditions.

8.3.2.4 Carbon

There are very little dissolved or particulate organic carbon data available for Willow Creek, only a few samples collected near the mouth. Organic carbon is derived from decaying plant material carried in surface runoff or produced by biological activity in the stream. Among the few observed values that do exist, dissolved organic carbon (DOC) predominates over particulate (POC) forms. Values tend to be less than comparable ones from in Mosquito Creek and Little Bow River (Hamilton & Brassard, 1983).

The carbon content of mountain runoff is often low; whereas the DOC in prairie snowmelt runoff is elevated due to leaching from dormant grasses and animal wastes. Instream carbon sources can also produce high organic carbon levels during summer low flow conditions. Claresholm water treatment practices (R. Chartrand, Town of Claresholm) confirm these factors affect Willow Creek Water quality. Dissolved organic carbon levels correlate with phenolics and color, both of which are hard to remove from drinking water. Color is aesthetically unpleasant and phenols impart taste and odour upon chlorination. At Claresholm taste and odour problems occur during February and March, and again during summer drought conditions.

Color, DOC and phenol concentrations in Willow Creek are probably at a minimum after lower foothill and prairie runoff is finished, and when mountain flows are adequate but not extreme, i.e. during May, July and early August.

8.3.2.5 Suspended Solids

Non-filterable residue (NFR) is a direct measure of suspended solids content. Turbidity is an indirect measure based upon light transmission through a unit volume of water. Turbidity and NFR are usually highly correlated. As there are little NFR data we will assume turbidity levels directly reflect suspended solid concentrations.

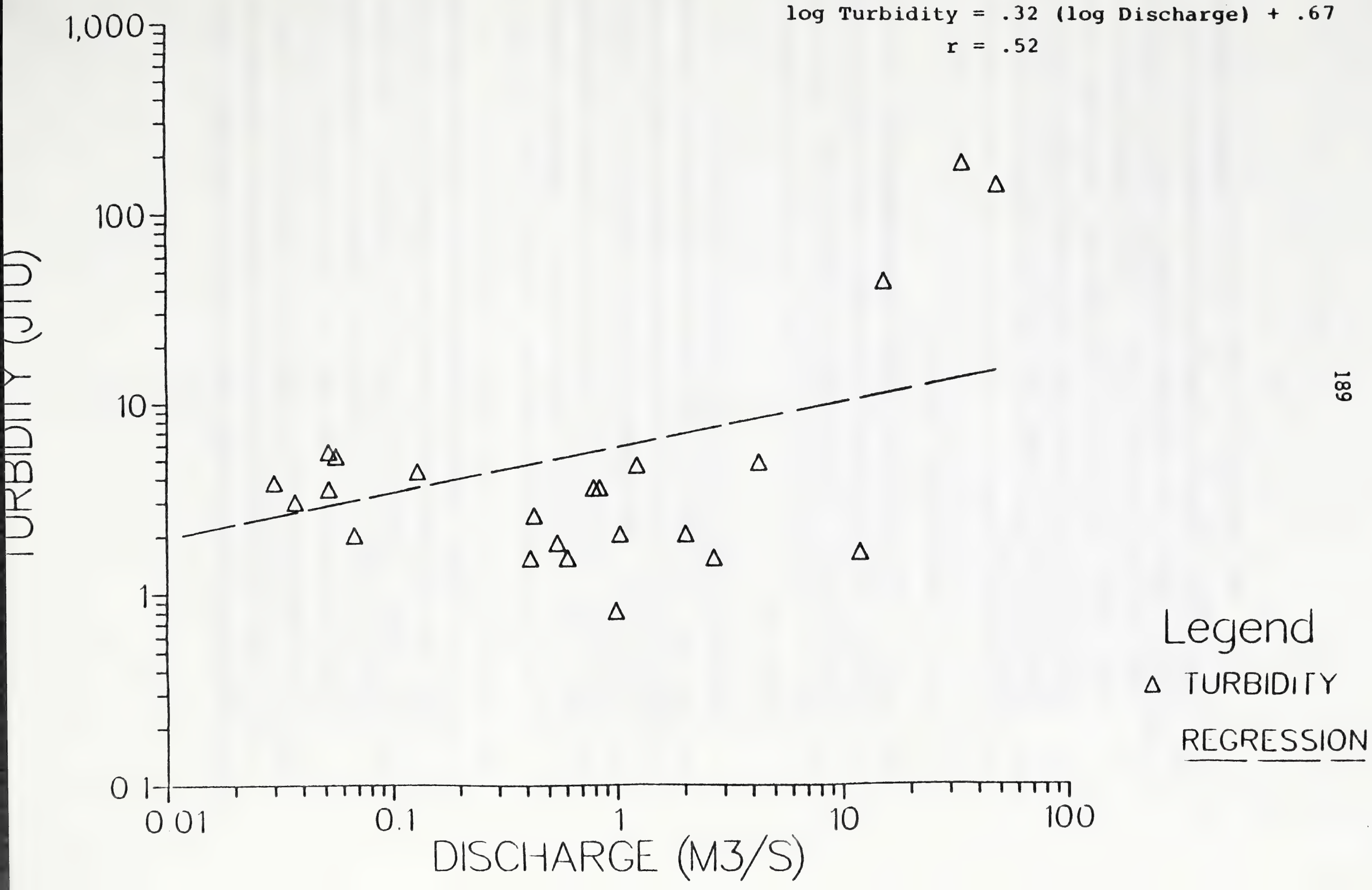
Turbidity is high in the early open water period and extremely low during the late summer and fall when flows decline. The relationship between discharge and turbidity is significant but not strong (Figure 8-4). Average early open water turbidity levels are lower at HWY 811 relative to the upper sites. A reduced gradient in this reach may result in particle sedimentation; or once again this may be an artifact of the sample distribution. The HWY 811 dataset may contain a greater proportion of data collected at low discharge values.

8.3.2.6 Nutrients

Nitrogen and phosphorus are the primary plant nutrients in aquatic systems. At high levels they stimulate weed and algal growth. Both are derived from municipal discharges and agricultural runoff, especially livestock rearing.

Total phosphorus (TP) concentrations at HWY 811 are high during the early season but are much reduced during the late summer and fall. There is a correlation between streamflow and TP (Table 8-5), however, the low correlation coefficient indicates other factors are significant. The particulate phosphorus form predominates over dissolved, especially in the spring. Upstream of Pine Coulee there are only two TP records; both of which are low. It is likely that average TP is less in the upper basin due to 1) the influence of mountain runoff, which is often low in TP, 2) sedimentation in Chain Lakes, and 3) reduced agricultural impact.

FIGURE 8-4 Relationship between discharge and turbidity for HWY 2 and HWY 811



Near the mouth of Willow Creek average ammonia concentrations range between 0.106 and 0.172 mg/l, which are comparable to levels in the lower Little Bow River and Mosquito Creek systems. Values are greater during the early openwater season. Ammonia sources include the Chain Lakes, surface runoff and instream processes. Late summer minima are a function of reduced inputs, nitrification and biological uptake by aquatic primary producers. Nitrate levels in Willow Creek are low relative to the Little Bow River.

8.3.2.7 Bacteriological Indicators

Fecal coliforms (FC) indicate contamination by warm blooded animals. Total coliforms (TC) are found in animal wastes but are also present in soils. The bacteriological database for Willow Creek is quite good due to the activities of Standards and Approvals Division, Alberta Environment.

Microbiological indicator densities are usually presented as geometric rather than arithmetic means; so geometric values are presented in (Table 8-4). Average total and fecal coliform counts are elevated in the early season, however, there is no downstream pattern. The 90% statistic does increase between U/S Pine Coulee and HWY 2. This means that 90% of all data are less than the indicated level, or conversely 10% of samples exceed.

The major source of these occasional high indicator densities would be animal waste input with runoff from grazing areas and feedlots. This pattern is consistant with the high occurance of feedlots on the downstream Claresholm area (Mike Bennett, Standards & Approvals Division, Alberta Environment). Total and fecal coliform levels do not correlate with discharge (Table 8-5), which may reflect variation in the proportion of streamflow contributed by local versus mountain runoff. Greatest coliform densitites would occur when local runoff is at a maximum.

8.3.2.8 Metals

Except for iron and manganese metals data have only been collected at Claresholm and HWY 2. Most of the early data were obtained in the early 1970's.

High iron levels occur during the early open water period. This reflects a correlation with turbidity and a non-point source origin. The manganese trend is similar to that of iron, however, interpretation of the dataset is impaired by detection limit variability.

Cadmium, mercury, nickel, chromium and lead concentrations remained at or near the analytical detection limit at both sampling locations. Levels are comparable to those observed in the Little Bow River system.

8.3.3 COMPARISON OF HISTORICAL WATER QUALITY WITH OBJECTIVES

The Alberta Surface Water Quality Objectives (ASWO) are broad based objectives intended to protect all water uses (Standards & Approvals Division, 1977) (Table 8-6). Willow Creek water quality exceeds the ASWO objective levels for bacteriological parameters, pH, total phosphorus, iron and manganese.

The ASWO microbiological guidelines were not violated for water to be withdrawn for municipal treatment or used for non-contact recreation. The total and fecal coliform objectives for direct contact recreation and vegetable crop irrigation are exceeded in the lower basin approximately 10% of the time.

High pH, iron and manganese concentrations relative to the ASWO all relate to municipal water treatment requirements and domestic supply. High pH interferes with the disinfection process and accentuates corrosion

TABLE 8-6 SURFACE WATER QUALITY OBJECTIVES

(see explanatory notes for definition of parameters)

These objectives represent water quality suitable for most uses either through direct use or prepared for use by an economically practical degree of treatment. They apply to surface waters except in areas of close proximity to outfalls.

There are many instances where the natural water quality of a lake or river does not meet some of the suggested limits. In these cases, the limits obviously will not apply. It should be noted, however, that where the natural existing quality is inferior to desirable criteria, it would be unwise to permit further deterioration by unlimited or uncontrolled introduction of pollutants. Naturally occurring circumstances are not taken into account in these objectives and due consideration must be given where applicable (e.g. spring runoff effect on colour, odour, etc.).(8)

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1. Bacteriology (Coliform Group)

   (a) In waters to be withdrawn for treatment and distribution as a potable supply or used for outdoor recreation other than direct contact, at least 90 per cent of the samples (not less than five samples in any consecutive 30-day period) should have a total coliform density of less than 5,000 per 100 ml and a fecal coliform density of less than 1,000 per 100 ml.

   (b) In waters used for direct contact recreation or vegetable crop irrigation the geometric mean of not less than five samples taken over not more than a 30-day period should not exceed 1,000 per 100 ml total coliforms, nor 200 per 100 ml fecal coliforms, nor exceed these numbers in more than 20 per cent of the samples examined during any month, nor exceed 2,400 per 100 ml total coliforms on any day.

2. Dissolved Oxygen

   A minimum of five mg/l at any time.

3. Biochemical Oxygen Demand

   Dependent on the assimilative capacity of the receiving water, the BOD must not exceed a limit which would create a dissolved oxygen content of less than five mg/l.

4. Suspended Solids

   Not to be increased by more than 10 mg/l over background value.

5. pH

   To be in the range of 6.5 to 8.5 pH units but not altered by more than 0.5 pH units from background value.

6. Temperature

   Not to be increased by more than 3°C above ambient water temperature.

7. Odour

   The cold (20°C) threshold odour number not to exceed eight.

8. Colour

   Not to be increased more than 30 colour units above natural value.

9. Turbidity

   Not to exceed more than 25 Jackson units over natural turbidity.

TABLE 8-6 CONTINUED

10. **Organic Chemicals**

Constituent	Maximum Concentration (mg/l)
Carbon Chloroform Extract (CCE) (includes Carbon Alcohol Extract)	0.2
Methyl Mercaptan	0.05
Methylene Blue Active Substances	0.5
Oil and Grease	substantially absent, no irridescent sheen
Phenolics	0.005
Resin Acids	0.1

11. **Pesticides**

To provide reasonably safe concentrations of these materials in receiving waters an application shall not exceed 1/100 of the 48-hour Tl_m. No pesticides can be used in Alberta unless they have been registered under the Pest Control Products Act. Any pesticides used on, in, or near water (within 100 linear feet) must be approved by a Department of Environment permit issued under The Agricultural Chemicals Act.

12. **Toxic Chemicals**

Constituent	Maximum Concentration (mg/l)
Arsenic	0.01
Barium	1.0
Cadmium	0.01
Chromium	0.05
Cyanide	0.01
Lead	0.05
Mercury	0.0001
Selenium	0.01
Silver	0.05

13. **Radioactivity**

Gross Beta not to exceed 1,000 pCi/l.
Radium 226 not to exceed three pCi/l.
Strontium 90 not to exceed 10 pCi/l.

14. **Inorganic Chemicals**

Constituent	Maximum Concentration (mg/l)
Boron	0.5
Copper	0.02
Fluoride	1.5
Iron	0.3
Manganese	0.05
Nitrogen (Total Inorganic and Organic)	1.0
Phosphorus as PO_4 (Total Inorganic and Organic) ...	0.15
Sodium (as percent of cations)	between 30 & 75
Sulphide	0.05
Zinc	0.05

NOTE: The predominant cations of SODIUM, CALCIUM and MAGNESIUM and anions of SULPHATE, CHLORIDE and BICARBONATE are too variable in the natural water quality state to attempt to define limits. Nevertheless, in order to prevent impairment of water quality, where effluents containing these ions are discharged to a water body the permissible concentration will be determined by the administrative authority in accordance with existing quality and use.

15. **Unspecified Substances**

Substances not specified herein should not exceed values which are considered to be deleterious for the most critical use as established by the administrative authority.

in municipal distribution systems. The Town of Claresholm water treatment facility has pH adjustment capabilities (D. Fisher, Pollution Control Division, Alberta Environment). High iron and manganese levels are of aesthetic rather than public health concern. They can result in staining of laundry and porcelain plumbing fixtures.

Total phosphorus concentrations in the lower basin are of concern relative to the ASWO because of its stimulatory effect upon aquatic plant and algal growth. Although little data exist, it is probable the objective for TP is not exceeded in the reach near Chain Lakes. The other important plant nutrient is nitrogen. There are insufficient data to test the ASWO for total nitrogen, however, it is likely exceeded in the lower basin on occasion.

The ASWO objective for dissolved oxygen (5 mg/l) is met during the open water season, however, winter data are lacking. Some of the organic constituents included in the ASWO, like carbon chloroform extract, methyl mercaptan, ethylene blue active substances, oil and grease and resin acids could not be evaluated. However, observed phenolic concentrations were less than the ASWO level. Data from the Little Bow River basin implies that the phenolic criterion may be exceeded during local runoff.

Specific use water quality objectives allow for more detailed evaluation of water use suitability. The specific use objectives employed here (Tables 8-7,8-8) were adapted from the set used for the South Saskatchewan River Basin Planning Program (Hamilton, 1983). They were specially designed for southern Alberta conditions, and include objectives for water to be treated for public supply, cold and warm water fish, contact and non-contact recreation, irrigation and livestock watering.

During the open water interval the warm water fishery objectives have not been exceeded for oxygen or temperature, whereas, based upon the

TABLE 8-7 Water Quality Criteria for Public Water Supplies

Parameter	Recommended Limit	
Aldrin + Dieldrin	0.0007	mg/l
Arsenic	0.05	"
Barium	1.0	"
Boron	5.0	"
Cadmium	0.005	"
Carboryl	0.07	"
Cesium - 137	50.	Bg/l
Chlordane (total isomers)	0.007	mg/l
Chloride	250.	"
Chromium	0.05	"
Coliforms, fecal	1000.	/100 ml
Coliforms, total	5000.	/100 ml
Colour, true	15.	TCU
Copper	1.0	mg/l
Cyanide, free	0.2	"
Diazinon	0.014	"
Endrin	0.0002	"
Fluoride	1.5	"
Hepachlore + heptachlor epoxide	0.003	"
Iodine - 131	10.	Bq/l
Lead	0.05	mg/l
Lindane	0.004	"
Manganese	0.05	"
Methoxychlor	0.1	"
Methyl Parathion	0.007	"
Mercury	0.001	"
Nitrate, as N	10.0	"
Nitrite, as N	1.0	"
Nitrilotriacetic acid	0.05	"
Parathion	0.035	"
pH	6.58.5	units
Phenolics	0.002	mg/l
Radium - 226	1.0	Bq/l
Selenium	0.01	mg/l
Silver	0.05	"
Strontium - 90	10.	Bq/l
Sulphate	500.	mg/l
Sulphide, as H S	0.05	mg/l
Toxachene	0.005	"
Trihalomethanes	0.35	"
Tritium	40,000.	Bq/l
2, 4 - D	0.1	mg/l
2, 4, 5 - TP	0.01	"
Total Pesticides	0.1	'
Uranium	0.02	"
Zinc	5.0	"

TABLE 8-8 SUMMARY OF SPECIFIC USE WATER QUALITY OBJECTIVES (ADAPTED FROM HAMILTON(1983)). UNITS mg/l UNLESS OTHERWISE INDICATED.

	COLD WATER FISHERY		WARM WATER FISHERY		CONTACT RECREATION		NON-CONTACT RECREATION		IRRIGATION		LIVESTOCK	
	PRIMARY	SECONDARY	PRIMARY	SECONDARY	PRIMARY	SECONDARY	PRIMARY	SECONDARY	PRIMARY	SECONDARY	PRIMARY	SECONDARY
CONDUCTIVITY(us/cm)									2,500	1,000		
TOTAL DISSOLVED SOLIDS											5,000	1,500
TEMPERATURE(^{o}C)	23	22	29	28	20							
OXYGEN	4.0	5.0	3.0	4.0								
UNIONIZED AMMONIA	0.04	0.03	0.04	0.03								
TROPHIC STATE		HYPER		HYPER	EUT	MESO	HYPER	EUT		HYPER		
TOTAL COLIFORMS(/100ml)					1,000		4,000			1,000		
FECAL COLIFORMS(/100ml)					200							
SAR(rel.units)									9	4		
TURBIDITY(JTU)					50							

(MESO) MESOTROPHIC
(EUT) EUTROPHIC
(HYPER) HYPTERTROPHIC

PRIMARY = LIMITING TO USE
SECONDARY = IMPACTING ON USE

1981 diurnal dataset the temperature criterion for coldwater fish was exceeded in the lower basin. Un-ionized ammonia could not be evaluated, however, since there are no point source ammonia discharges it is of lesser concern relative to temperature and oxygen.

As for the ASWO, the pH and manganese objectives for raw public water supply are exceeded in Willow Creek. The specific use objective for iron includes the dissolved form, for which no data exist. Fecal coliform densities at HWY 2 on occasion exceed the recommended limit, which implies extra care is required in the water treatment process. The municipal supply objective for phenolics (0.002 mg/l) is exceeded at HWY 811, however, little or no upstream data are available. Chlorinated phenolics cause taste and odour in drinking water. Claresholm experiences taste and odour problems in March when the local prairie runoff occurs, and during extremely low flow summer conditions (R. Chartrand, Pers.Comm.). Color is also a problem at those times.

According to the available data the specific use objectives for non-contact recreation, and livestock watering are not violated anywhere during the open water season. The total dissolved solids and SAR content of the creek is adequate for irrigation, however, at certain times bacteriological quality would impair use for vegetable crop irrigation. Similarly, total and fecal coliform densities limit contact recreation suitability throughout the system.

8.3.4 Water Quality Impacts

There are no direct industrial discharges to Willow Creek, and only the towns of Claresholm and Granum are of sufficient size to have a municipal discharge. Mr. Dave Fisher (Pollution Control Division, Alberta Environment) indicates all of the sewage lagoon effluent at Claresholm is used for irrigation, with no discharge to Willow Creek. Granum is licensed to discharge to the creek, however, its current sewage lagoon capacity is large enough that evaporation handles all inputs. This should continue to be the case for sometime to come.

Although there are no direct effluent discharges to the system, Willow Creek water quality is impacted by non-point source inputs. Enhanced sodium sulphate levels indicate significant groundwater input to lower stream reaches, i.e. downstream from Claresholm.

Diffuse source agricultural inputs have the largest impact on Willow Creek Quality. A study by Standards and Approvals Division of Alberta Environment (1982) indicated a total of 615 existing livestock operations in the Municipal District of Willow Creek, the majority of these being small to medium size cattle operations (85%). None of the feedlots have a direct effluent discharge to Willow Creek and only one (Prime Feeders) has a voluntary livestock handling facility certificate of compliance (Mike Bennett, Pers.Comm.) Most of the intensive livestock operations within close proximity to Willow Creek are located downstream of Claresholm. Some of these operations actually water their cattle directly on the creek. The effect of these agricultural wastes is evidenced by elevated coliform densities and total phosphorus concentrations in the downstream Claresholm reach. The impact is greatest at periods of high local runoff, i.e. during early spring snowmelt and major rainstorms.

8.3.5 Aquatic Weeds and Algae

Nuisance aquatic weed and algal growth reduce water conveyance capacity, clog water intakes and diversion structures and impact on water quality. Nuisance growth has occurred in the Bow and Oldman rivers downstream of Calgary and Lethbridge (Charlton et al, 1985) and in the Little Bow River basin (Hamilton and Brassard, 1982).

With minor exceptions aquatic plant productivity has not been a major problem in the Willow Creek Basin. An overview flight in June, 1985 indicated only minor growth in the channel upstream from Claresholm. Local irrigators have not been expressing concern about pump clogging like farmers along the Little Bow and Highwood Rivers (D. Duncan and L. Szojka, Planning Division, Alberta Environment). Granum has not not experienced difficulty with their water intake (R Kutt, Town of Granum), and at Claresholm weed impairment only occurred during late summer 1984 when river flows were very low (R. Chartrand, Town of Claresholm). However, it is Mr. Chartrand's observation that weed growth in the creek has increased in recent years. The author has observed significant plant production near HWY 811 north of Ft. McLeod. This is a low gradient stretch were the water is relatively deep and slow moving.

Aquatic plant growth is dependant upon substate characteristics, nutrient levels and the longterm hydrologic regime (Haslam, 1978). Lack of a point source municipal effluent discharge likely helps to limit Willow Creek plant production. Prolific growth occurs in effluent enriched zones downstream of High River (Hamilton, 1983) and Calgary (Charlton et al, 1985). Nutrient inputs from agricultural runoff may enhance growth in the zone downstream from Granum.

A fine depositional substate also favors establishment of rooted aquatic plants (macrophytes). Even if water column nutrient levels are low, macrophytes can derive nitrogen and phosphorus from fine grained sediment particles. Substrate in the upper basin is largely gravel and cobble whereas a greater proportion of silt and sand occurs downstream from HWY 2.

The observation that plant growth is increasing may relate to the recent hydrologic regime. In the last decade southern Alberta river flows has also been generally low. This means the degree and magnitude of the runoff spates have been reduced. Through time this contributes to establishment of macrophyte root zones, which expand from year to year. They are only destroyed when flows are of sufficient magnitude that bed movement occurs. For example the Little Bow River system does not experience a significant spring spate and aquatic plant production is extensive.

8.3.6 Reservoir Site Selection

Reservoir site selection relative to water quality conditions is dependant upon trophic status, recreation potential, oxygen depletion, initial quality impairment and downstream water quality enhancement. Each of these are discussed below and then ranked by site in a summary table which forms the site selection recommendation.

8.3.6.1 Trophic Status

Trophic state is a measure of a waterbody's biological productivity. Oligotrophic lakes and reservoirs are unproductive; plant and algal growth is minimal, water clarity is high and fish production low. Eutrophic systems are located at the other end of the trophic scale. They are characterized by high primary productivity, can have dense summer blue-green algae blooms, and rooted aquatic plants usually achieve high densities in shallow nearshore areas. Algal production reduces overall water clarity in eutrophic lakes. Mesotrophic waterbodies are intermediate between oligotrophic and eutrophic, whereas hypertrophic systems represent the extreme upper scale. Reservoirs in southern Alberta range all the way from oligotrophic to hypertrophic (Table 8-9).

Trophic state is dependant upon nutrient loadings, basin morphometry and flushing rate. In southern Alberta low productivity reservoirs often have a low total phosphorus (TP) content, rapid flushing rate and intermediate depth. Little Bow, Waterton, St. Mary and Chin are southern Alberta examples of such oligotrophic to mesotrophic reservoirs.

TABLE 8-9 CHEMICAL AND PHYSICAL CHARACTERISTICS OF SOME SOUTHERN ALBERTA RESERVOIRS. DATA IS LARGELY DERIVED FROM MONITORING DONE IN 1983-1984 (CHARLTON, 1985)

	X TP	X CHL	SURFACE AREA	X DEPTH	MAX DEPTH	VOLUME	FLUSHING RATE	X TURB	X COND	PROBABLE TROPHIC STATE BASED ON TP	PROBABLE TROPHIC STATE BASED ON CHLORPHYLL	SECCHI
	mg/l	mg/m^3	ha	m	m	dam^3	1/yr	JTU	us/cm			m
TRAVERS	0.015	2.3	2,307	14.5	39.6	334,560	0.7	2	369	O-M	O-M	3.91
MCGREGOR	0.027	8.9	10,700	8.5	9.0	325,665	-	3	336	M-E	M-E	1.74
LITTLE BOW	0.014	1.9	748	5.2	14.0	39,052	6.0	2	368	O-M	O-M	3.33
CHESTERMERE	0.033	5.9	275	3.9	7.0	6,150	-	3	323	M-E	M-E	2.82
NEWELL	0.029	11.1	5,844	9.0	13.9	177,392	-	2	345	M-E	M-E	2.34
LITTLE FISH	0.880	77.1	761	1.1	2.5	-	-	24	1734	H	H	0.42
KEHO	0.040	2.7	1,861	0.7	3.2	-	-	13	310	M-E	O-M	0.82
HANNA	0.870	36.9	25	2.4	3.5	-	-	13	1139	H	H	0.45
BERRY CK.	0.750	77.3	567	1.7	3.0	-	-	5	830	H	H	1.28
BLD. INDIAN	0.370	10.4	107	2.5	3.5	-	-	4	2294	H	M-E	2.08
EAGLE	0.388	-	-	2.7	-	31,130	-	15	1866	H	-	0.40
CLEAR	1.080	-	268	1.9	-	5,087	-	40	4972	H	-	0.21
PAINE	0.025	-	244	3.7	-	8,908	-	1	209	M	-	2.50
WATERTON	0.007	-	1,094	16.1	-	172,519	7.2	2	207	O	-	3.90
ST. MARY	0.021	-	3,715	10.4	-	38,745	5.0	2	195	O-M	-	1.15
CHIN (STAFFORD)	0.015	-	263	4.4	-	205,410	17.0	2	295	O-M	-	1.75
CHAIN LK.	-	-	321	5.4	9.1	17,300	-	2	306	-	-	-

O - OLIGOTROPHIC
M - MESOTROPHIC
E - EUTROPHIC
H - HYPERTROPHIC

Deep reservoirs with a lower flushing rate can also be unproductive, i.e. Travers. Shallow reservoirs with a longer water retention time often tend to fall within the mesotrophic to eutrophic categories, i.e. Chestermere, Newell and Keho. It should be noted that the above comparison (Table 8-9) was made possible by a recent reservoir data collection project undertaken by Alberta Environment (S. Charlton, Pers.Comm.).

Input streams, atmospheric deposition and bottom sediment release are all nutrient loading sources. There are insufficient data to calculate probable nutrient loadings to each reservoir site from Willow Creek. Loadings calculated with TP data characteristic of Willow Creek near the mouth would probably result in poor reservoir trophic status. However, it is estimated stream TP concentrations in the reach between Chain Lakes and Pine Coulee are less. Nutrient release from sediments can occur under aerobic (Mitchell,1984; Reynoldson and Hamilton, 1982) or anaerobic conditions (Riley & Prepas, 1984). Wind mixing and sediment resuspension of nutrients is a probable cause of observed high productivity in shallow reservoirs. The lesser mean depths of the Pine Coulee and Pine Coulee/Willow Creek (Table 8-10) sites imply their sediment nutrient loading rates may be greater relative to sites one or two which have mean depths of 13.7m and 20m respectively. The greater surface area to volume ratio at sites two and four also mean higher relative atmospheric nutrient loading rates.

As noted above rapid flushing rates tend to favour reduced productivity. This has been verified elsewhere in North America and Europe (Placke Cox, 1984; Clasen & Bernhardt, 1980). Flushing rates will be greater for the three onstream sites relative to the offstream Pine Coulee site (Table 8-10). These calculations are based upon information provided in the Klohn Leonoff report (1984) and N. Wimer (Alberta Environment, pers. comm.). Depending upon the operating regime the Pine Coulee flushing rate may actually be less than that indicated. This calculation assumes diverting an average of 54% of Willow Creek through the Pine Coulee reservoir.

TABLE 8-10 RESERVOIR MORPHOMETRY

	$\bar{X}$ DEPTH	MAX DEPTH	STORAGE CAPACITY	AVERAGE FLUSHING RATE	SURFACE AREA TO VOLUME
	M	M	dam^3	1/yr	m^2/m^3
SITE 1	13.7	27	39,000	1.41	0.073
SITE 2	9.4	21	50,500	0.78	0.107
SITE 3	20.0	46	59,000	1.62	0.050
SITE 4	8.2	23	72,570	1.46	0.121

In addition to the relationship between mean depth and sediment re-suspension, morphometry also effects productivity through nutrient trapping and relative size of the epilimnetic zone. Very deep reservoirs, like site three (46m maximum depth), develop a summer thermocline (temperture gradient) which traps nutrients in the bottom of the reservoir (hypolimnion) after they settle out of the surface waters (epilimnion). The epilimnion then becomes nutrient deficient and algal growth is restricted. Shallow reservoirs, like sites 2 and 4, tend to circulate completely all summer thereby re-supplying nutrients to the surface water zone from the bottom waters and sediments. The lesser surface area to volume ratio of deep reservoirs also means the zone of plant growth and therefore total algal production is reduced relative to shallow reservoirs with the same storage capacity.

Based upon the factors discussed above, and comparison of each proposed site with existing southern Alberta reservoirs (Table 8-9), we estimate onstream sites one and three will be oligotrophic to mesotrophic, whereas Pine Coulee sites will probably range from mesotrophic to eutrophic. The Willow Creek/Pine Coulee (site 4) reservoir would probably have a trophic state quite similar to that of site 2. One would expect the enhanced flushing rate created by the onstream dam to favour an improved trophic state, however, short circuiting may limit this effect. Close proximity of the Willow Creek inlet to the dam and reservoir release point could limit water exchange at the far end of the reservoir. The degree of this short circuiting will depend upon the operating and drawdown regime.

8.3.6.2 Oxygen Depletion

Summer fish kills caused by oxygen depletion should not be a problem at any of the three sites. Such kills tend to occur in hypertrophic systems in conjunction with specific climatological conditions (Papst et al 1980). Summer oxygen depletion of bottom water zones depend largely upon development of a thermocline, which inturn is dependant upon reservoir depth and wind activity. The extreme depth and sheltered nature of site three means that some thermal stratification of the bottom water could occur at this location. However this tendency might be counteracted by reservoir drawdown from the hypolimnion.

Winter oxygen depletion is common in southern Alberta lakes and reservoirs (Wes English, Fish and Wildlife Division, ENR). Complete oxygen depletion, and therefore winterkill of fish, is a function of mean depth, productivity and sediment surface area (Babin & Prepas, 1985). Considering the average depth and productivity of all four potential sites none should undergo complete winter deoxygenation. The low productivity and morphometry of sites one and three imply that bottom water oxygen deficits would be minimal or non-existent. Although data are limited, Chain Lake appears to remain completely oxygenated throughout the winter. Greater surface area to volume ratios, and their probable mesotrophic to eutrophic classification, might result in some bottom water oxygen deficits at the Pine Coulee sites (two and four).

8.3.6.3 Recreational Water Quality

Recreational water quality is primarily dependant upon plant and algal growth, water clarity and bacteriological conditions.

Relative to plant and algal growth sites one and three are slightly preferable to sites two and four. The mesotrophic to eutrophic projection for the latter two sites means greater average algal growth and frequency of blooms. Rooted aquatic plant growth depends upon shoreline slope and drawdown regime. The three sites cannot be compared for this factor due to lack of morphometric and operating regime data.

The turbidity of the Pine Coulee sites could be higher than that of sites one or three. As mentioned previously the sediment resuspension factor is greater due to their shallower depth, and a higher relative percentage of fines and clays in the banks of Pine Coulee may result in higher erosion rates. Bedrock formations mean that site three would have the greatest bank stability.

Bacteriological quality of mid-lake regions in southern Alberta reservoirs tends to always be suitable for contact recreation (Charlton, 1985). Localized nearshore problems arise due to livestock activity in the vicinity of swimming beaches. For all three potential sites the extent of this problem would depend upon the degree of direct livestock access to shoreline areas.

8.3.6.4 Initial Conditions After Flooding

Water quality and biological conditions in a reservoir go through a transitory stage for the first few years after flooding. Subsequent to that the system achieves a relative steady state. During the first years there is often a trophic upsurge due to nutrient release from innundated vegetation and soils. The larger bottom area of the Pine Coulee and Pine Coulee/Willow Creek sites means initial loading from soil innundation may be greater at these locations.

Site surveillance also indicates substantial salt deposition in the bottom of Pine Coulee, which is not apparent for sites one and three. Elevated salt concentrations will occur in reservoirs that flood Pine Coulee until such time as the soils are depleted. The magnitude and duration of this salt elevation would be a function of flushing rate and soil chemistry. The effect should be of shorter duration for the onstream dam at Pine Coulee (site 4) because of its enhanced flushing rate relative to the offstream location.

Mercury release from newly innundated terrestrial soils is a current concern (Bodaly et al, 1984). Mercury tends to accumulate in fish tissues rather than show up as elevated concentrations in the water column. This may impact on fishery use of all four sites for the first few years, and will definitely require monitoring.

8.3.6.5 Downstream Water Quality Enhancement

A prime purpose for storage in the Willow Creek Basin is enhancement of municipal water supply at Claresholm and Granum.

Current water quality relative to municipal supply is poor during February and March, and occasionally during very low flow conditions in late summer, i.e. 1984. Colour, along with taste and odour, results from organics in the local snowmelt runoff. The June mountain runoff does not contain the same organics load, however, turbidity levels are elevated. Turbidity increases the degree of municipal treatment required, but by and large does not effect the finished water. Extreme summer low flows result in taste and odour problems because of organics derived from the stream channel. Unlike the Little Bow River winter water quality does not appear to be a problem in the Willow Creek Basin, only quantity. The high organic content of the Little Bow River channel results in under ice oxygen depletion, which inturn degrades quality.

Based upon current water quality patterns, offstream drinking water reservoirs should be filled anytime other than during the local(i.e. prairie)runoff period. Turbidity is high during mountain runoff in June, however, this is rapidly removed by sedimentation in the storage reservoir.

Expanded storage at any of the four locations will not appreciably improve drinking water quality in February and March, as much of the local runoff will enter the channel between the point of reservoir release and the municipal intakes. Enhanced summer and fall flows should prevent drought related water quality problems. Onstream storage would reduce high flow turbidity levels and therefore reduce water treatment costs.

During drawdown periods, when natural flows are low, reservoir conditions will largely determine downstream quality, as instream processes appear not to be a major factor. It is therefore important that reservoir quality be optimized. The projected better trophic status makes sites one and three preferable to Pine Coulee sites two and four. Algal productivity can result in taste and odour problems at certain times of the year. During winter months it is also important that deoxygenated bottom waters not be discharged to the stream system. The risk of this is slightly greater at Pine Coulee, however any potential problem could likely be operationally controlled.

During the first few years after impoundment organic leachates from innundated soils and vegetation will probably create some downstream taste and odour problems, however, these would diminish with time. Initial release of sodium sulphate from Pine Coulee could also impact initial drinking water quality.

All the reservoirs are deep enough that winter water temperatures will probably remain near 4°C. Such temperatures will help to prevent downstream channel icing during extreme cold weather. The extent of this effect will depend upon discharge rate and ambient air temperature. Similarly, summer water temperatures will be reduced below the reservoir release. Depending upon the reservoir location this could extend the cold water fishery zone further downstream.

One last consideration is aquatic plant growth. Regulation of the Willow Creek basin will dampen the June high Flows. This may result in elevated macrophyte densities which could, at certain times of the year, increase operating costs to clean water intakes.

The analysis reported here is based upon qualitative analysis and general comparison with similar reservoirs in southern Alberta. Once the site selection is narrowed to one or two locations modelling could be carried out to more quantitatively predict trophic status, winter and summer oxygen, shoreline erosion rates and reservoir salinity. Inturn, such tools could be used to optimize filling and drawdown regimes.

Table 8-11 presents an overall ranking of the four potential reservoir sites based upon the major factors discussed above.

TABLE 8-11 RESERVOIR SITE SELECTION BASED UPON WATER QUALITY CONSIDERATIONS

	SITE 1	SITE 2	SITE 3	SITE 4
TROPHIC STATUS				
STREAM NUTRIENT LOADINGS	1	1	1	1
SEDIMENT NUTRIENT LOADINGS	1	0	1	0
MORPHOMETRY	1	0	2	0
FLUSHING RATE	1	0	1	0.5
OXYGEN CONDITIONS				
SUMMER	1	1	1	1
WINTER	1	0.5	1	1
RECREATION WATER QUALITY				
TROPHIC STATE	1	0.5	1	0.5
TURBIDITY	1	0.5	1	0.5
BACTERIOLOGY	1	1	1	1
INITIAL CONDITIONS AFTER FLOODING	0.5	0	1	0.5
DOWNSTREAM WATER QUALITY ENHANCEMENT				
SPRING TASTE & ODOUR	1	1	1	1
SUMMER AND FALL	2	1.5	2	1.5
WINTER	2	1.5	2	1.5
AVERAGE	1.16	0.65	1.23	0.77

(0) NEGATIVE (1) NEUTRAL (2) POSITIVE

8.4 CONCLUSIONS

1. The reach from Chain Lakes to Claresholm is controlled by mountain runoff and releases from Chain Lakes; water quality is good to very good. Downstream of Claresholm groundwater inputs and agricultural activities reduce quality. This is a common pattern characteristic of streams which originate on the east slopes and flow onto the prairie.

2. Poorest water quality is experienced during the prairie snowmelt interval (March and April), and again during major June and July rainfalls. At those times soluble organic compounds, suspended solids and nutrients are transported into the stream due to surface runoff. High streamflows originating from mountain runoff are of better quality.

3. Certain of the Alberta Surface Water Quality Objectives are exceeded, especially in lower basin reaches, due to natural factors and non-point source impacts. There are no municipal or industrial discharges to Willow Creek.

4. Summer water quality of Willow Creek will sustain a warm water fishery. High temperatures in the lower reaches are limiting to cold water fish.

5. Relative to use of Willow Creek for withdrawal and treatment for domestic supply; high natural pH levels necessitate pH control, and manganese levels may at times result in staining of plumbing fixtures. In early spring, and again during summer drought flows, high soluble organic concentrations can result in color, and taste and odour problems. Occasional high total and fecal coliform levels necessitate the need for careful chlorination practices, particularly in the lower reaches.

6. The stream remains suitable for non-contact recreation, but contact recreation objectives are exceeded part of the time.

7. Use of the stream for livestock watering is never limited by water quality, however, direct access of cattle to the stream channel impacts stream quality for certain parameters.

8. Ongoing problems with nuisance aquatic plant and algal growth have not been experienced along Willow Creek. However, in recent years plant densities appear to have been increasing in the lower reaches. This increase is likely a result of non-point source nutrient loading and sustained low river flows.

9. From a water quality perspective, sites 1 and 3 are preferable to the two offstream Pine Coulee locations. The shallower mean depth and lesser flushing rate will result in a reduced trophic status at site 2. Conditions might be slightly improved at site 4 (Willow Creek/Pine Coulee).

10. Immediately after filling reservoir quality will be impaired for the first few years. The extent of this initial trophic upsurge and elevated salinity will be greatest at the Pine Coulee location. This will effect downstream municipal supplies for an undetermined time period.

11.. Elevated summer streamflows resulting from reservoir release will prevent the poor water quality conditions currently experienced in Willow Creek during drought conditions. Existing winter quality is adequate and should not be appreciably altered by reservoir releases. Local runoff will still impact municipal supplies during March and April.

12. Stream regulation will likely enhance aquatic plant (macrophyte) growth in the Willow Creek channel.

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APPENDICES I, II, AND III

9.0 APPENDIX I

Wildlife Habitat Suitability Models

9.1 MULE DEER HABITAT SUITABILITY MODEL

9.1.1 Existing Models/Data bases

Habitat requirements of mule deer in Alberta have been summarized by Kramer (1978), Green et al. (1984) and Nietfeld et al. (1984). IEC Beak (1984) provides a model for rating suitability of broad-scale land units for this species on a province-wide basis.

9.1.2 Major Habitat Requirements

Cover Type. Mule deer are found in a broad variety of vegetation types but prefer native shrubland, parkland and forest cover. During spring and summer, shrublands and deciduous forests provide adequate thermal and hiding cover; conifer forests provide the best cover during winter but dense deciduous vegetation also is used. Land clearing decreases habitat value by reducing available cover.

Forbes and deciduous browse are the major food items, although graminoids are used to some extent, primarily during spring. Forbe use also occurs during late spring and summer. Browse is used year-round and is the major dietary component during the fall and winter period, when ground vegetation may be largely unavailable due to snow cover. Optimum foraging habitat is provided by low shrubs and trees interspersed with openings, and with a drinking water source (snow-free period only) nearby. Agricultural crops may be used year-round where available, but cultivation and overgrazing generally decrease forage availability.

Slope Characteristics. Mule deer are found primarily in association with rough, broken terrain, preferring moderate to steep slopes for escape and thermal cover.

Aspect. Traditional wintering areas with little snow accumulation are critically important to this species. Such areas are generally found in association with southerly exposures and offer thermal advantages as well as improved access to food sources. Use of warm slopes continues through the spring period as these are the first to green-up. All aspects are used during summer.

9.1.3 Model Development (see Tables 9-1)

General. Availability of optimum habitat is considered most critical during fall/winter. Consequently, only a fall/winter model has been developed for this species.

Fall/Winter. During winter, suitable thermal and escape cover is critically important, and this is reflected in assignment of a higher weighting to the cover submodel (0.6) than to the food submodel (0.4).

Cover is provided mainly by vegetation types with a coniferous or dense deciduous component. The availability of steep slopes and southerly aspects (providing geomorphic cover, reduced snow depth and higher temperatures) also is important during this period, but these variables have been weighted lower in significance than cover type.

Food selection during winter is strongly influenced both by cover type and aspect, and these are given equal weightings in the food submodel. Cover type/aspect combinations providing browse and/or other forage above snow are required during this period and the variable categories are ranked on this basis.

9.1.4 Calculation of Habitat Suitability

The following formulae were used to determine the suitability of each land system polygon as mule deer habitat:

Fall/Winter Cover Value

$[0.6 \times \Sigma(\text{cover type rating} \times \text{proportion of cover type in land system})]$
$+ [0.2 \times \text{slope rating}] + [0.2 \times \text{aspect rating}]$

Fall/Winter Food Value

$[0.6 \times \Sigma(\text{cover type rating} \times \text{proportion of cover type in land system})]$
$+ [0.4 \times \text{aspect rating}]$

Habitat Suitability Rating (HSR)

$\text{HSR} = (0.6 \times \text{fall/winter cover}) + (0.4 \times \text{fall/winter food})$

Habitat Suitability Index (HSI)

HSI = HSR/3

Table: 9-1 Willow Creek Wildlife Capability Model - Mule Deer

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Fall/ Winter	0.6	Cover	0.6	Cover type	0	-bare soil/rock
					1	-seasonal wetland
					1	-permanent wetland/ open water
					0	-native grassland
					0	-improved pasture
					0	-cropland
					1	-shrub meadow (10-50% shrub cover)
					2	-shrubland (>50% shrub cover)
					2	-conifer parkland (10-50% tree cover)
					1	-deciduous parkland
					3	-conifer forest (>50% tree cover)
					2	-deciduous forest (>50% tree cover)
					2	-mixed forest (>50% tree cover)
			0.2	Slope characteristics	3	-steep, broken (>30° slopes predominate)
					2	-moderate, rolling (10-30°)
					1	-flat (<10°)
			0.2	Major aspects	1	-cool slopes (W-N-SE)
					3	-warm slopes (SE-S-W)
					1	-flat
			N/A	Stream permanency		-intermittent
						-permanent
			N/A	Stream sinuosity		-straight
						-curved
						-meandering

Table: 9-1 (cont'd) Willow Creek Wildlife Capability Model - Mule Deer

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Fall/ Winter	0.4	Food	0.6	Cover type	0	-bare soil/rock
					1	-seasonal wetland
					1	-permanent wetland/ open water
					1	-native grassland
					1	-improved pasture
					1	-cropland
					2	-shrub meadow (10-50% shrub cover)
					3	-shrubland (>50% shrub cover)
					1	-conifer parkland (10-50% tree cover)
					2	-deciduous parkland
					1	-conifer forest (>50% tree cover)
					3	-deciduous forest (>50% tree cover)
					2	-mixed forest (>50% tree cover)
			N/A	Slope characteristics		-steep, broken (>30° slopes predominate)
						-moderate, rolling (10-30°)
						-flat (<10°)
			0.4	Major aspect	1	-cool slopes (W-N-SE)
					3	-warm slopes (SE-S-W)
					2	-flat
			N/A	Stream permanency		-intermittent
						-permanent
			N/A	Stream sinuosity		-straight
						-curved
						-meandering

Table 9-2. Habitat availability summary- Willow Creek Mule Deer

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Fl1.lF	333.1	0.17	0.18	0.34	114.76
2	Cw2.tS	10	0.20	0.24	0.44	4.40
3	Cw3.eS	3.8	0.24	0.16	0.40	1.52
4	Fc3.eF	6.5	0.16	0.13	0.29	1.91
5	Fc2.eF	20.6	0.14	0.12	0.26	5.33
6	Bo3.iN	5.7	0.16	0.05	0.21	1.22
7	Mg1.lF	1340	0.09	0.13	0.23	303.02
8	Fc2.lF	3.1	0.20	0.11	0.31	0.96
9	Fc1.eF	0.6	0.08	0.13	0.21	0.13
10	Cw2.iN	15.9	0.14	0.15	0.29	4.66
11	Mg3.rF	5.6	0.16	0.13	0.29	1.64
12	Cw2.iS	1.6	0.20	0.24	0.44	0.70
13	Mg2.vF	6.1	0.12	0.13	0.25	1.55
14	Bo3.eS	21.7	0.24	0.16	0.40	8.68
15	Bo3.iS	1.7	0.24	0.16	0.40	0.68
16	Fw2.iS	34.3	0.20	0.23	0.43	14.87
17	Fc2.eS	1.4	0.20	0.24	0.44	0.62
18	Cw3.iS	13.2	0.24	0.24	0.48	6.34
19	Fw2.tS	43.2	0.20	0.40	0.60	25.92
20	Cw3.lS	4.1	0.24	0.24	0.48	1.97
21	Cw3.iN	29.2	0.40	0.13	0.53	15.57
22	Mw2.mF	3.4	0.12	0.19	0.31	1.05
23	Fc1.gF	4.7	0.32	0.13	0.45	2.13

TOTAL AREA = 1910.5 TOTAL HABITAT UNITS = 519.63

HABITAT UNITS PER HA = 0.27

Table 9-3. Habitat availability summary-Pine Coulee (Site 2) Mule Deer

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Bo3.eS	2.7	0.00	0.00	0.00	0.00
2	Bo3.lF	0.5	0.00	0.00	0.00	0.00
3A	Cw2.iS	30.7	0.20	0.24	0.44	13.43
3	Cw2.iS	45.6	0.00	0.00	0.00	0.00
4A	Cw2.iN	68.9	0.12	0.14	0.26	17.87
4	Cw2.iN	57.3	0.00	0.00	0.00	0.00
5	Cw1.iN	24.7	0.00	0.00	0.00	0.00
6A	Cw2.tN	20.4	0.02	0.09	0.11	2.20
6	Cw2.tN	46.6	0.12	0.05	0.17	8.08
7A	Cw3.iS	43.4	0.24	0.24	0.48	20.83
7	Cw3.iS	33.5	0.00	0.00	0.00	0.00
8	Cw3.eS	0.8	0.00	0.00	0.00	0.00
9A	Cw3.iN	12.5	0.40	0.29	0.69	8.67
9	Cw3.iN	27	0.00	0.00	0.00	0.00
10	Cw3.cN	10.5	0.00	0.00	0.00	0.00
11	Ff1.iS	5.1	0.00	0.00	0.00	0.00
12A	Ff1.lF	0	0.08	0.11	0.19	0.00
12	Ff1.lF	3.5	0.00	0.00	0.00	0.00
13A	Ff1.iN	1.5	0.08	0.13	0.21	0.32
13	Ff1.iN	3.9	0.00	0.00	0.00	0.00
14	Fc1.lF	17.3	0.00	0.00	0.00	0.00
15	Ff2.lF	22.9	0.00	0.00	0.00	0.00
16A	Ff2.iN	1.1	0.12	0.13	0.25	0.28
16	Ff2.iN	2.4	0.00	0.00	0.00	0.00
17A	Fc2.gF	13.1	0.16	0.21	0.37	4.88
17	Fc2.gF	41.7	0.00	0.00	0.00	0.00
18	Fc2.iF	3.9	0.00	0.00	0.00	0.00
19A	Fc2.gS	3.5	0.20	0.24	0.44	1.54
19	Fc2.gS	3.4	0.00	0.00	0.00	0.00
20A	Fc2.gN	2.4	0.12	0.13	0.25	0.61
20	Fc2.gN	12.9	0.00	0.00	0.00	0.00
21	Ft2.tN	2.6	0.00	0.00	0.00	0.00
22A	Fc3.gF	8.5	0.16	0.11	0.27	2.27
22	Fc3.gF	18.8	0.00	0.00	0.00	0.00
23A	Fc3.gN	7.6	0.20	0.16	0.35	2.69
23	Fc3.gN	1.4	0.00	0.00	0.00	0.00
24	Gw1.lF	22.2	0.01	0.00	0.01	0.32
25	Oz3.rF	2.9	0.00	0.00	0.00	0.00
26A	Mg1.hF	82	0.08	0.19	0.27	21.87
26	Mg1.hF	13.8	0.00	0.00	0.00	0.00
27A	Mg1.lF	799.6	0.08	0.19	0.27	216.74
27	Mg1.lF	811.9	0.00	0.00	0.00	0.00
28	Mg2.mF	81.7	0.00	0.00	0.00	0.00
29A	Gg1.lF	114.7	0.14	0.22	0.36	41.28
29	Gg1.lF	173.5	0.00	0.00	0.00	0.00

TOTAL AREA= 2704.9 TOTAL HABITAT UNITS= 363.87

HABITAT UNITS PER HA = 0.13

Table 9-4. Habitat availability summary-Pine Coulee (Site 4) Mule Deer

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Bo3.eS	2.7	0.00	0.00	0.00	0.00
1A	Bo3.eS	11.3	0.24	0.16	0.40	4.52
2	Bo3.lF	0.5	0.00	0.00	0.00	0.00
3A	Cw2.tS	40.5	0.20	0.24	0.44	17.72
3	Cw2.iS	45.6	0.00	0.00	0.00	0.00
4A	Cw2.iN	108.3	0.15	0.15	0.30	32.24
4	Cw2.iN	57.3	0.00	0.00	0.00	0.21
5	Cw1.iN	24.7	0.00	0.08	0.08	1.98
6A	Cw2.tN	20.4	0.14	0.14	0.28	5.74
6	Cw2.tN	46.6	0.00	0.00	0.00	0.00
7A	Cw3.tS	64.7	0.24	0.24	0.48	31.00
7	Cw3.tS	33.5	0.00	0.00	0.00	0.00
8	Cw3.eS	0.8	0.00	0.00	0.00	0.00
8A	Cw3.eS	2.7	0.24	0.24	0.48	1.30
9A	Cw3.iN	23.6	0.29	0.22	0.51	11.93
9	Cw3.iN	27	0.00	0.00	0.00	0.00
10	Cw3.gN	10.5	0.00	0.00	0.00	0.00
11	Ff1.tS	5.1	0.00	0.00	0.00	0.00
12A	Ff1.lF	15.4	0.20	0.27	0.47	7.19
12	Ff1.lF	3.5	0.00	0.00	0.00	0.00
13A	Ff1.iN	1.5	0.08	0.13	0.21	0.32
13	Ff1.iN	3.9	0.00	0.00	0.00	0.00
14	Fc1.lF	17.3	0.00	0.00	0.00	0.00
15	Ff2.lF	22.9	0.00	0.00	0.00	0.00
16A	Ff2.iN	1.1	0.12	0.13	0.25	0.28
16	Ff2.iN	2.4	0.00	0.00	0.00	0.00
17A	Fc2.gF	20	0.16	0.22	0.38	7.61
17	Fc2.gF	41.7	0.00	0.00	0.00	0.00
18	Fc2.iF	3.9	0.00	0.00	0.00	0.00
19A	Fc2.gS	3.5	0.20	0.24	0.44	1.54
19	Fc2.gS	3.4	0.00	0.00	0.00	0.00
20A	Fc2.gN	2.4	0.17	0.16	0.33	0.79
20	Fc2.gN	12.9	0.00	0.00	0.00	0.00
21	Ft2.tN	2.6	0.00	0.00	0.00	0.00
22A	Fc3.gF	133.9	0.17	0.19	0.36	48.19
22	Fc3.gF	27.3	0.00	0.00	0.00	0.00
23A	Fc3.gN	7.6	0.20	0.16	0.35	2.69
23	Fc3.gN	1.4	0.00	0.00	0.00	0.00
24	Gw1.lF	22.2	0.00	0.00	0.00	0.00
25	Oz3.rF	2.9	0.00	0.00	0.00	0.00
26A	Mg1.hF	82	0.08	0.19	0.27	21.87
26	Mg1.hF	13.8	0.00	0.00	0.00	0.00
27A	Mg1.lF	988.1	0.08	0.19	0.27	265.07
27	Mg1.lF	799.1	0.00	0.00	0.00	0.00
28	Mg2.mF	81.7	0.00	0.00	0.00	0.00
28A	Mg2.mF	229.2	0.12	0.19	0.31	71.02
29A	Gg1.lF	114.7	0.14	0.22	0.36	41.28
29	Gg1.lF	173.5	0.00	0.00	0.00	0.00
30	Bo3.eN	2.6	0.04	0.05	0.09	0.24
31	Ff1.tF	43.8	0.20	0.13	0.33	14.31
32	Oz2.hF	2.1	0.12	0.11	0.23	0.48
33	Ff1.lF	218.8	0.28	0.21	0.49	106.92

TOTAL AREA = 3628.9 TOTAL HABITAT UNITS = 696.42

HABITAT UNITS PER HA = 0.19

Table 9-5. Habitat availability summary- Kuntz Creek Mule Deer

SYSTEM NUMBER	LAND SYSTEM	TOTAL AREA	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Bc3.eN	1.7	0.16	0.05	0.21	0.36
2	Bc3.eF	0.7	0.16	0.11	0.27	0.19
3	Bc3.eS	6.3	0.24	0.16	0.40	2.52
4	Cw2.iF	6.5	0.12	0.11	0.23	1.47
5	Cw2.iS	10.5	0.20	0.16	0.36	3.78
6	Cw3.iN	139.7	0.38	0.21	0.59	82.94
7	Cw3.iS	121.7	0.34	0.30	0.64	77.79
8	Ft1.lF	102.1	0.11	0.19	0.30	30.78
9	Ff1.lF	8.5	0.11	0.21	0.32	2.74
10	Ff1.iN	13.6	0.10	0.14	0.24	3.28
11	Ft1.lS	9.4	0.16	0.24	0.40	3.76
12	Ft1.iS	15.2	0.31	0.34	0.65	9.91
13	Fc3.eN	23.3	0.25	0.19	0.45	10.38
14	Fc1.gF	0.7	0.32	0.35	0.67	0.47
15	Fc2.gN	6.8	0.28	0.24	0.52	3.52
16	Ft2.iN	9.3	0.18	0.15	0.33	3.04
17	Ft3.tN	25.7	0.40	0.23	0.63	16.19
18	Fc3.gN	70.7	0.29	0.22	0.52	36.43
19	Fc3.gS	61.1	0.36	0.36	0.72	43.80
20	Fh3.gF	81.3	0.25	0.24	0.49	39.73
21	Mg1.lF	73.3	0.11	0.21	0.31	23.07
22	Mg1.iN	30	0.11	0.15	0.27	7.96
23	Mg2.mF	122.6	0.22	0.25	0.46	56.87
24	Mg2.lS	1.5	0.20	0.24	0.44	0.66
25	Mg2.mN	170.6	0.28	0.24	0.53	89.76
26	Mg2.hN	94.2	0.32	0.26	0.58	55.10
27	Mg2.hF	188.2	0.13	0.20	0.33	61.86
28	Mg2.iS	155.3	0.20	0.24	0.44	68.33
29	Mg2.iN	21.2	0.12	0.05	0.17	3.67
30	Mg2.mS	50.8	0.20	0.16	0.36	18.29
31	Oz3.hF	2.7	0.16	0.11	0.27	0.72
32	Fl1.lF	204.9	0.18	0.25	0.43	88.33

TOTAL AREA = 1830.1 TOTAL HABITAT UNITS = 847.70

HABITAT UNITS PER HA = 0.46

9.2 ELK HABITAT SUITABILITY MODEL

9.2.1 Exiting Models/Data bases

Nietfeld et al. (1984) highlight elk habitat requirements in the province as a whole, based on a review of literature from Alberta and from elsewhere in western North America, and IEC Beak (1984) presents a model, based on the above information review, for rating habitat suitability of large, biophysical land units throughout the province. Green et al. (1985) provide a detailed review of elk habitat requirements specific to the mountain and foothills region of Alberta.

9.2.2 Major Habitat Requirements

Cover Type. Good elk habitat consists of open forage-producing sites interspersed with forested areas and/or geomorphic features providing escape and thermal cover. Habitat availability is restricted by snow cover in winter, but summer range is more widely dispersed. Sites providing 60-75% open foraging area with the rest in thermal/hiding cover are considered to be optimal winter habitat.

Elk subsist primarily on graminoids year-long, although, in some areas, browse (mainly willows and other deciduous species, but including some conifers) becomes a major dietary constituent during summer-fall. Forbes are little used during any season. The major foraging habitat is provided by open and sparsely treed grassland communities, but shrublands and deciduous, coniferous and mixedwood forests also are used for foraging to some extent. Some use also is made of seeded grasslands and agricultural crops (haystacks and grainfields). Use made of foraging areas varies with distance to cover and with disturbance factors.

Slope Characteristics. Elk habitat is located primarily in valley bottoms and on adjacent benches and gentle to moderate slopes. Steep, hilly terrain is used for escape and shelter.

Aspect. Year-long activity primarily occurs on southerly slopes (i.e., east through south to west). During winter, elk concentrate in areas of reduced snow depth, primarily on west to south-facing slopes and in valley bottoms.

9.2.3 Model Development (see Table 9-6)

General. Considering the dependence of elk on traditional wintering areas, the availability of optimum habitat conditions is considered to be most critical during fall/winter. Consequently, only a fall/winter model has been developed for this species.

Fall/Winter. Adequate cover and the availability of areas with reduced snow depth for foraging are considered equally important during winter, and consequently the food and cover submodels are weighted equally (0.5) for the fall/winter period.

Cover is provided mainly by vegetation, but topography and slope also are important. Dense woody vegetation, steep, broken topography and warm (i.e., southerly) slopes are considered to provide the best cover conditions.

Food availability during winter depends largely on cover type and aspect, the optimum combination being grass-producing cover types on warm slopes. Topography is included in the submodel due to its influence on snow accumulation; steep, warm slopes are most likely to be snow free.

9.2.4 Calculation of Habitat Suitability

The following formulae were used to determine the suitability of each land system polygon as elk habitat:

Fall/Winter Cover

[0.5 x Σ(cover type rating x proportion of cover type in land system)] + [0.3 x slope rating] + [0.2 x aspect]

Fall/Winter Food

[0.5 x Σ(cover type rating x proportion of cover type in land system)] + [0.2 x slope rating] + [0.3 x aspect rating]

Habitat Suitability Rating (HSR)

HSR = (0.5 x fall/winter cover) + (0.5 x fall/winter food)

Habitat Suitability Index (HSI)

HSI = HSR/3

Table: 9-6 Willow Creek Wildlife Capability Model - Elk

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Fall/ Winter	0.5	Cover	0.5	Cover type	0	-bare soil/rock
					0	-seasonal wetland
					0	-permanent wetland/ open water
					0	-native grassland
					0	-improved pasture
					0	-cropland
					1	-shrub meadow (10-50% shrub cover)
					2	-shrubland (>50% shrub cover)
					2	-conifer parkland (10-50% tree cover)
					1	-deciduous parkland
					3	-conifer forest (>50% tree cover)
					2	-deciduous forest (>50% tree cover)
					2	-mixed forest (>50% tree cover)
			0.3	Slope characteristics	3	-steep, broken (>30° slopes predominate)
					2	-moderate, rolling (10-30°)
					1	-flat (<10°)
			0.2	Major aspects	1	-cool slopes (W-N-SE)
					3	-warm slopes (SE-S-W)
					2	-flat
			N/A	Stream permanency		-intermittent
						-permanent
			N/A	Stream sinuosity		-straight
						-curved
						-meandering

Table: 9-6 (cont'd) Willow Creek Wildlife Capability Model - Elk

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Fall/ Winter	0.5	Food	0.5	Cover type	0	-bare soil/rock
					1	-seasonal wetland
					1	-permanent wetland/ open water
					3	-native grassland
					2	-improved pasture
					1	-cropland
					3	-shrub meadow (10-50% shrub cover)
					2	-shrubland (>50% shrub cover)
					3	-conifer parkland (10-50% tree cover)
					3	-deciduous parkland
					1	-conifer forest (>50% tree cover)
					1	-deciduous forest (>50% tree cover)
					1	-mixed forest (>50% tree cover)
			0.2	Slope characteristics	3	-steep, broken (>30° slopes predominate)
					2	-moderate, rolling (10-30°)
					1	-flat (<10°)
			0.3	Major aspects	1	-cool slopes (W-N-SE)
					3	-warm slopes (SE-S-W)
					2	-flat
			N/A	Stream permanency		-intermittent
						-permanent
			N/A	Stream sinuosity		-straight
						-curved
						-meandering

Table 9-7. Habitat availability summary- Willow Creek Elk

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI FOOD	HSI COVER	HSI TOTAL	HABITAT UNITS
1	Fl1.lF	333.1	0.31	0.17	0.48	160.72
2	Cw2.tS	10	0.50	0.20	0.70	7.00
3	Cw3.eS	3.8	0.18	0.25	0.43	1.65
4	Fc3.eF	6.5	0.38	0.22	0.60	3.90
5	Fc2.eF	20.6	0.43	0.17	0.59	12.22
6	Bo3.iN	5.7	0.08	0.18	0.27	1.52
7	Mg1.lF	1340	0.24	0.12	0.36	476.82
8	Fc2.lF	3.1	0.26	0.17	0.42	1.31
9	Fc1.eF	0.6	0.42	0.12	0.53	0.32
10	Cw2.iN	15.9	0.38	0.15	0.53	8.48
11	Mg3.rF	5.6	0.38	0.22	0.60	3.36
12	Cw2.iS	1.6	0.50	0.20	0.70	1.12
13	Mg2.vF	6.1	0.28	0.17	0.45	2.75
14	Bo3.eS	21.7	0.18	0.25	0.43	9.40
15	Bo3.tS	1.7	0.18	0.25	0.43	0.74
16	Fw2.iS	34.3	0.48	0.20	0.68	23.32
17	Fc2.eS	1.4	0.50	0.20	0.70	0.98
18	Cw3.iS	13.2	0.43	0.25	0.68	9.02
19	Fw2.tS	43.2	0.50	0.20	0.70	30.28
20	Cw3.lS	4.1	0.43	0.25	0.68	2.80
21	Cw3.iN	29.2	0.25	0.27	0.52	15.09
22	Mw2.mF	3.4	0.38	0.17	0.54	1.85
23	Fc1.gF	4.7	0.33	0.20	0.53	2.51

TOTAL AREA = 1910.5 TOTAL HABITAT UNITS= 777.15

UNITS PER HA = 0.41

Table 9-8. Habitat availability summary- Pine Coulee (Site 2) Elk

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Bo3.eS	2.7	0.00	0.00	0.00	0.00
2	Bo3.lF	0.5	0.00	0.00	0.00	0.00
3A	Cw2.iS	30.7	0.20	0.46	0.66	20.24
3	Cw2.iS	45.6	0.00	0.00	0.00	0.00
4A	Cw2.iN	68.9	0.14	0.29	0.42	29.11
4	Cw2.iN	57.3	0.00	0.00	0.00	0.00
5	Cw1.iN	24.7	0.00	0.00	0.00	0.00
6A	Cw2.tN	20.4	0.15	0.37	0.51	10.44
6	Cw2.tN	46.6	0.01	0.00	0.01	0.23
7A	Cw3.iS	43.4	0.25	0.50	0.75	32.44
7	Cw3.lS	33.5	0.00	0.00	0.00	0.00
8	Cw3.eS	0.8	0.00	0.00	0.00	0.00
9A	Cw3.iN	12.5	0.35	0.32	0.67	8.33
9	Cw3.iN	27	0.00	0.00	0.00	0.00
10	Cw3.gN	10.5	0.00	0.00	0.00	0.00
11	Ff1.iS	5.1	0.00	0.00	0.00	0.00
12A	Ff1.lF	0	0.12	0.13	0.25	0.00
12	Ff1.lF	3.5	0.00	0.00	0.00	0.00
13A	Ff1.iN	1.5	0.08	0.17	0.25	0.38
13	Ff1.iN	3.9	0.00	0.00	0.00	0.00
14	Fc1.lF	17.3	0.00	0.00	0.00	0.00
15	Ff2.lF	22.9	0.00	0.00	0.00	0.00
16A	Ff2.iN	1.1	0.13	0.28	0.42	0.46
16	Ff2.iN	2.4	0.00	0.00	0.00	0.00
17A	Fc2.gF	13.1	0.19	0.42	0.61	8.00
17	Fc2.gF	41.7	0.00	0.00	0.00	0.00
18	Fc2.iF	3.9	0.00	0.00	0.00	0.00
19A	Fc2.gS	3.5	0.20	0.47	0.67	2.33
19	Fc2.gS	3.4	0.00	0.00	0.00	0.00
20	Fc2.gN	12.9	0.00	0.00	0.00	0.00
20A	Fc2.gN	2.4	0.13	0.28	0.42	1.00
21	Ft2.tN	2.6	0.00	0.00	0.00	0.00
22A	Fc3.gF	8.5	0.22	0.20	0.42	3.54
22	Fc3.gF	18.8	0.00	0.00	0.00	0.00
23A	Fc3.gN	7.6	0.21	0.39	0.60	4.53
23	Fc3.gN	1.4	0.00	0.00	0.00	0.00
24	Gw1.lF	22.2	0.12	0.13	0.25	5.55
25	Oz3.rF	2.9	0.00	0.00	0.00	0.00
26A	Mg1.hF	82	0.12	0.28	0.40	32.39
26	Mg1.hF	13.8	0.00	0.00	0.00	0.00
27A	Mg1.lF	799.6	0.12	0.28	0.39	313.84
27	Mg1.lF	811.9	0.00	0.00	0.00	0.00
28	Mg2.mF	81.7	0.00	0.00	0.00	0.00
29A	Gg1.lF	114.7	0.16	0.38	0.53	60.98
29	Gg1.lF	173.5	0.00	0.00	0.00	0.00

TOTAL AREA= 2704.9 TOTAL HABITAT UNITS= 533.80

HABITAT UNITS PER HA = 0.20

Table 9-9. Habitat availability summary-Pine Coulee (Site 4) Elk

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Bo3.eS	2.7	0.00	0.00	0.00	0.00
1A	Bo3.eS	11.3	0.25	0.25	0.50	5.65
2	Bo3.lF	0.5	0.00	0.00	0.00	0.00
3A	Cw2.iS	40.5	0.20	0.46	0.66	26.70
3	Cw2.iS	45.6	0.00	0.00	0.00	0.00
4A	Cw2.iN	108.3	0.15	0.13	0.29	30.87
4	Cw2.iN	57.3	0.00	0.00	0.00	0.00
5	Cw1.iN	24.7	0.00	0.00	0.00	0.00
6A	Cw2.tN	20.4	0.15	0.37	0.51	10.44
6	Cw2.tN	46.6	0.00	0.00	0.00	0.00
7A	Cw3.iS	64.7	0.25	0.49	0.74	47.61
7	Cw3.iS	33.5	0.00	0.00	0.00	0.00
8	Cw3.eS	0.8	0.00	0.00	0.00	0.00
8A	Cw3.eS	2.7	0.25	0.50	0.75	2.03
9A	Cw3.iN	23.6	0.27	0.36	0.63	14.81
9	Cw3.iN	27	0.00	0.00	0.00	0.00
10	Cw3.gN	10.5	0.00	0.00	0.00	0.00
11	Ff1.iS	5.1	0.00	0.00	0.00	0.00
12A	Ff1.lF	15.4	0.12	0.13	0.25	3.85
12	Ff1.lF	3.5	0.00	0.00	0.00	0.00
13A	Ff1.iN	1.5	0.08	0.33	0.42	0.62
13	Ff1.iN	3.9	0.00	0.00	0.00	0.00
14	Fo1.lF	17.3	0.00	0.00	0.00	0.00
15	Ff2.lF	22.9	0.00	0.00	0.00	0.00
16A	Ff2.iN	1.1	0.13	0.37	0.50	0.55
16	Ff2.iN	2.4	0.00	0.00	0.00	0.00
17A	Fc2.gF	20	0.19	0.44	0.64	12.72
17	Fc2.gF	41.7	0.00	0.00	0.00	0.00
18	Fc2.iF	3.9	0.00	0.00	0.00	0.00
19A	Fc2.gS	3.5	0.20	0.47	0.67	2.33
19	Fc2.gS	3.4	0.00	0.00	0.00	0.00
20A	Fc2.gN	2.4	0.17	0.35	0.51	1.22
20	Fc2.gN	12.9	0.00	0.00	0.00	0.00
21	Ft2.tN	2.6	0.00	0.00	0.00	0.00
22A	Fc3.gF	133.9	0.22	0.44	0.67	89.04
22	Fc3.gF	27.3	0.00	0.00	0.00	0.00
23A	Fc3.gN	7.6	0.21	0.39	0.60	4.53
23	Fc3.gN	1.4	0.00	0.00	0.00	0.00
24	Gw1.lF	22.2	0.00	0.00	0.00	0.00
25	Oz3.rF	2.9	0.00	0.00	0.00	0.00
26A	Mg1.hF	82	0.12	0.28	0.40	32.39
26	Mg1.hF	13.8	0.00	0.00	0.00	0.00
27A	Mg1.lF	988.1	0.12	0.28	0.40	391.95
27	Mg1.lF	799.1	0.00	0.00	0.00	0.00
28	Mg2.mF	81.7	0.00	0.00	0.00	0.00
28A	Mg2.mF	229.2	0.17	0.39	0.56	128.16
29A	Gg1.lF	114.7	0.16	0.38	0.53	60.98
29	Gg1.lF	173.5	0.00	0.00	0.00	0.00
30	Bo3.eN	2.6	0.18	0.15	0.33	0.87
31	Ff1.tF	43.8	0.14	0.16	0.30	13.14
32	Oz2.hF	2.1	0.17	0.17	0.33	0.70
33	Ff1.lF	218.8	0.20	0.24	0.44	96.45

TOTAL AREA = 3628.9 TOTAL HABITAT UNITS = 977.60

Table 9-10. Habitat availability summary- Kuntz Creek Elk

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Bc3.eN	1.7	0.18	0.08	0.27	0.45
2	Bc3.eF	0.7	0.22	0.13	0.35	0.25
3	Bc3.eS	6.3	0.25	0.18	0.43	2.73
4	Cw2.iF	6.5	0.17	0.20	0.37	2.38
5	Cw2.iS	10.5	0.20	0.25	0.45	4.73
6	Cw3.iN	139.7	0.33	0.39	0.73	101.28
7	Cw3.iS	121.7	0.30	0.78	1.08	131.03
8	Ft1.lF	102.1	0.12	0.18	0.30	30.54
9	Ff1.lF	8.5	0.14	0.18	0.32	2.71
10	Ff1.iN	13.6	0.10	0.12	0.22	2.96
11	Ft1.lS	9.4	0.15	0.22	0.37	3.45
12	Ft1.iS	15.2	0.20	0.32	0.52	7.97
13	Fc3.eN	23.3	0.22	0.15	0.36	8.43
14	Fo1.gF	0.7	0.28	0.25	0.53	0.37
15	Fc2.gN	6.8	0.24	0.21	0.45	3.05
16	Ft2.iN	9.3	0.17	0.17	0.34	3.17
17	Ft3.tN	25.7	0.30	0.22	0.52	13.24
18	Fc3.gN	70.7	0.27	0.38	0.65	46.19
19	Fc3.gS	61.1	0.35	0.49	0.84	51.22
20	Fh3.gF	81.3	0.26	0.20	0.46	37.19
21	Mg1.lF	73.3	0.13	0.19	0.31	22.97
22	Mg1.iN	30	0.10	0.13	0.23	6.98
23	Mg2.mF	122.6	0.18	0.25	0.43	52.62
24	Mg2.lS	1.5	0.20	0.25	0.45	0.68
25	Mg2.mN	170.6	0.19	0.26	0.45	77.34
26	Mg2.hN	94.2	0.21	0.29	0.49	46.16
27	Mg2.hF	188.2	0.17	0.21	0.38	71.36
28	Mg2.iS	155.3	0.20	0.25	0.45	69.89
29	Mg2.iN	21.2	0.13	0.15	0.28	6.01
30	Mg2.mS	50.8	0.20	0.25	0.45	22.86
31	Ot3.hF	2.7	0.22	0.13	0.35	0.95
32	Fl1.lF	204.9	0.17	0.43	0.59	121.06

TOTAL AREA = 1830.1

TOTAL HABITAT UNITS = 952.18

HABITAT UNITS PER HA = 0.52

9.3 MOOSE HABITAT SUITABILITY MODEL

9.3.1 Existing Models/Data bases

General reviews of moose habitat requirements, incorporating information from various areas of Alberta, have been prepared by Haywood and Shackleton (n.d.), Rolley and Keith (1979), Thompson et al. (1980), Green et al. (1984) and Nietfeld et al. (1984). Green et al. (1985) review moose habitat requirements specific to the mountain and foothills region of the province. IEC Beak (1984) provides a biophysical model for use in rating habitat suitability of land units throughout Alberta.

9.3.2 Major Habitat Requirements

Cover Type. Moose utilize a variety of vegetation types, with habitat selection and seasonal movements being related primarily to forage availability. However, escape cover and shelter are required in proximity to foraging areas. Deciduous, conifer and mixed woods all are used for both escape and thermal cover; in summer, lakes and streams also may be used for thermoregulation and escape from biting flies.

Moose are primarily browsers throughout the year, willows being the major browse species used in western North America. Graminoids and aquatic plants also are used to some extent during the snow-free period. Shrublands provide the major foraging habitat, but forests also are used for feeding if sufficient browse is available.

Slope Characteristics. Although moose do occupy very mountainous areas throughout much of Alberta, the majority of their activity in winter occurs on relatively flat terrain, such as vegetated flood plains, valley bottoms and low slopes. Preference for such areas appears to be related to forage availability.

Aspect. Moose can tolerate greater snow depths than other cervids, and hence do not depend on snow-free winter ranges, provided that a good browse supply is available. Although most winter use occurs in flat areas, south to west-facing slopes also are used.

9.3.3 Model Development (see Table 9-11)

General. As with other ungulates, the critical period for moose is fall/winter, and a model has been developed for this season only.

Fall/Winter. Due to the reported strong correlation between level of moose utilization of a site and weight of winter browse available, the food submodel is given a heavier weighting (0.6) than the cover submodel (0.4) for the fall/winter period.

Winter cover is provided primarily by vegetation, conifer cover being considered most valuable, followed by deciduous forest and shrubland. Topographic cover is not considered to be important, although warm slopes and flats may provide thermoregulatory advantages compared to cool slopes.

Winter food availability is determined largely by cover type, but as valley bottoms are favored during winter, slope characteristics are also assigned some importance. Browse-producing cover types on flat areas are considered to provide the best winter foraging habitat.

9.3.4 Calculation of Habitat Suitability

The following formulae were used to determine the suitability of each land system polygon as moose habitat:

Fall/Winter Cover Value

$[0.6 \times \Sigma(\text{cover type rating} \times \text{proportion of cover type in land system})]$
$+ [0.2 \times \text{aspect rating}] + [0.2 \times \text{slope rating}]$

Fall/Winter Food Value

$[0.8 \times \Sigma(\text{cover type rating} \times \text{proportion of cover type in land system})]$
$+ [0.2 \times \text{slope rating}]$

Habitat Suitability Rating (HSR)

$\text{HSR} = (0.4 \times \text{fall/winter cover}) + (0.6 \times \text{fall/winter food})$

Habitat Suitability Index (HSI)

HSI = HSR/3

Table: 9-11 Willow Creek Wildlife Capability Model - Moose

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Fall/ Winter	0.4	Cover	0.6	Cover type	0	-bare soil/rock
					0	-seasonal wetland
					1	-permanent wetland/ open water
					0	-native grassland
					0	-improved pasture
					0	-cropland
					1	-shrub meadow (10-50% shrub cover)
					2	-shrubland (>50% shrub cover)
					2	-conifer parkland (10-50% tree cover)
					1	-deciduous parkland
					3	-conifer forest (>50% tree cover)
					2	-deciduous forest (>50% tree cover)
					2	-mixed forest (>50% tree cover)
			0.2	Slope characteristics	0	-steep, broken (>30° slopes predominate)
					2	-moderate, rolling (10-30°)
					3	-flat (<10°)
			0.2	Major aspects	1	-cool slopes (W-N-SE)
					3	-warm slopes (SE-S-W)
					2	-flat
			N/A	Stream permanency		-intermittent
						-permanent
			N/A	Stream sinuosity		-straight
						-curved
						-meandering

Table:9-11 (cont'd) Willow Creek Wildlife Capability Model - Moose

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Fall/ Winter	0.6	Food	0.8	Cover type	0	-bare soil/rock
					0	-seasonal wetland
					1	-permanent wetland/ open water
					0	-native grassland
					0	-improved pasture
					0	-cropland
					2	-shrub meadow (10-50% shrub cover)
					3	-shrubland (>50% shrub cover)
					1	-conifer parkland (10-50% tree cover)
					1	-deciduous parkland
					2	-conifer forest (>50% tree cover)
					3	-deciduous forest (>50% tree cover)
					2	-mixed forest (>50% tree cover)
			0.2	Slope characteristics	1	-steep, broken (>30° slopes predominate)
					2	-moderate, rolling (10-30°)
					3	-flat (<10°)
			N/A	Major aspects		-cool slopes (W-N-SE)
						-warm slopes (SE-S-W)
						-flat
			N/A	Stream permanency		-intermittent
						-permanent
			N/A	Stream sinuosity		-straight
						-curved
						-meandering

Table 9-12. Habitat availability summary-Willow Creek Moose

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Fl1.lF	333.1	0.13	0.30	0.43	142.48
2	Cw2.tS	10	0.08	0.08	0.16	1.60
3	Cw3.eS	3.8	0.08	0.04	0.12	0.46
4	Fc3.eF	6.5	0.05	0.04	0.09	0.61
5	Fc2.eF	20.6	0.05	0.08	0.13	2.75
6	Bo3.iN	5.7	0.03	0.04	0.07	0.38
7	Mg1.lF	1340	0.05	0.12	0.18	238.70
8	Fc2.lF	3.1	0.05	0.08	0.13	0.41
9	Fc1.eF	0.6	0.05	0.12	0.17	0.10
10	Cw2.iN	15.9	0.05	0.13	0.18	2.80
11	Mg3.rF	5.6	0.05	0.04	0.09	0.52
12	Cw2.iS	1.6	0.08	0.08	0.16	0.26
13	Mg2.vF	6.1	0.05	0.08	0.13	0.81
14	Bo3.eS	21.7	0.08	0.04	0.12	2.60
15	Bo3.lS	1.7	0.08	0.04	0.12	0.20
16	Fw2.iS	34.3	0.08	0.08	0.16	5.49
17	Fc2.eS	1.4	0.08	0.08	0.16	0.22
18	Cw3.iS	13.2	0.08	0.04	0.12	1.58
19	Fw2.tS	43.2	0.08	0.08	0.17	7.21
20	Cw3.lS	4.1	0.08	0.04	0.12	0.49
21	Cw3.iN	29.2	0.24	0.04	0.28	8.18
22	Mw2.mF	3.4	0.05	0.08	0.13	0.45
23	Fc1.gF	4.7	0.27	0.12	0.39	1.82
	AREA =	1910.5			TOTAL UNITS =	420.13

UNITS PER HA = 0.22

Table 9-13. Habitat availability summary- Pine Coulee (Site 2) Moose

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Bo3.eS	2.7	0.08	0.12	0.20	0.54
2	Bo3.lF	0.5	0.05	0.08	0.13	0.07
3A	Cw2.iS	30.7	0.13	0.12	0.25	7.78
3	Cw2.iS	45.6	0.00	0.00	0.00	0.00
4A	Cw2.iN	68.9	0.08	0.05	0.13	9.09
4	Cw2.iN	57.3	0.00	0.00	0.00	0.00
5	Cw1.iN	24.7	0.11	0.04	0.15	3.62
6A	Cw2.tN	20.4	0.09	0.08	0.18	3.59
6	Cw2.tN	46.6	0.00	0.00	0.00	0.00
7A	Cw3.iS	43.4	0.08	0.28	0.36	15.62
7	Cw3.lS	33.5	0.00	0.00	0.00	0.00
8	Cw3.eS	0.8	0.08	0.12	0.20	0.16
9A	Cw3.iN	12.5	0.19	0.52	0.71	8.83
9	Cw3.iN	27	0.00	0.00	0.00	0.00
10	Cw3.gN	10.5	0.03	0.04	0.07	0.70
11	Ff1.iS	5.1	0.16	0.12	0.28	1.43
12A	Ff1.lF	0	0.13	0.08	0.21	0.00
12	Ff1.lF	3.5	0.00	0.00	0.00	0.00
13A	Ff1.lN	1.5	0.11	0.04	0.15	0.22
13	Ff1.iN	3.9	0.00	0.00	0.00	0.00
14	Fc1.lF	17.3	0.11	0.08	0.19	3.23
15	Ff2.lF	22.9	0.11	0.08	0.19	4.27
16A	Ff2.iN	1.1	0.08	0.20	0.28	0.31
16	Ff2.iN	2.4	0.00	0.00	0.00	0.00
17A	Fc2.gF	13.1	0.13	0.19	0.32	4.17
17	Fc2.gF	41.7	0.00	0.00	0.00	0.00
18	Fc2.iF	3.9	0.11	0.08	0.19	0.73
19A	Fc2.gS	3.5	0.13	0.12	0.25	0.89
19	Fc2.gS	3.4	0.00	0.00	0.00	0.00
20	Fc2.gN	12.9	0.00	0.00	0.00	0.00
20A	Fc2.gN	2.4	0.08	0.04	0.12	0.29
21	Ft2.tN	2.6	0.08	0.04	0.12	0.31
22A	Fc3.gF	8.5	0.05	0.08	0.13	1.13
22	Fc3.gF	18.8	0.00	0.00	0.00	0.00
23A	Fc3.gN	7.6	0.05	0.11	0.16	1.24
23	Fc3.gN	1.4	0.00	0.00	0.00	0.00
24	Gw1.lF	22.2	0.13	0.08	0.21	4.74
25	Oz3.rF	2.9	0.05	0.08	0.13	0.39
26A	Mg1.hF	82	0.13	0.08	0.21	17.49
26	Mg1.hF	13.8	0.00	0.00	0.00	0.00
27A	Mg1.lF	799.6	0.13	0.08	0.22	174.42
27	Mg1.lF	811.9	0.00	0.00	0.00	0.00
28	Mg2.mF	81.7	0.00	0.00	0.00	0.00
29A	Gg1.lF	114.7	0.17	0.27	0.44	50.62
29	Gg1.lF	173.5	0.00	0.00	0.00	0.00

TOTAL AREA= 2704.9

TOTAL HABITAT UNITS= 315.88

HABITAT UNITS PER HA = 0.12

Table 9-14. Habitat availability summary- Pine Coulee (Site 4) Moose

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Bo3.eS	2.7	0.00	0.00	0.00	0.00
1A	Bo3.eS	11.3	0.08	0.00	0.08	0.90
2	Bo3.lF	0.5	0.00	0.00	0.00	0.00
3A	Cw2.iS	40.5	0.13	0.08	0.21	8.64
3	Cw2.iS	45.6	0.00	0.00	0.00	0.00
4A	Cw2.iN	108.3	0.10	0.13	0.23	24.69
4	Cw2.iN	57.3	0.00	0.00	0.00	0.14
5	Cw1.iN	24.7	0.00	0.00	0.00	0.00
6A	Cw2.tN	20.4	0.09	0.12	0.22	4.41
6	Cw2.tN	46.6	0.00	0.00	0.00	0.00
7A	Cw3.iS	64.7	0.08	0.00	0.08	5.18
7	Cw3.iS	33.5	0.00	0.00	0.00	0.00
8	Cw3.eS	0.8	0.00	0.00	0.00	0.00
8A	Cw3.eS	2.7	0.08	0.00	0.08	0.22
9A	Cw3.iN	23.6	0.11	0.25	0.37	8.63
9	Cw3.iN	27	0.00	0.00	0.00	0.00
10	Cw3.gN	10.5	0.00	0.00	0.00	0.00
11	Ff1.iS	5.1	0.00	0.00	0.00	0.00
12A	Ff1.lF	15.4	0.13	0.12	0.25	3.90
12	Ff1.lF	3.5	0.00	0.00	0.00	0.00
13A	Ff1.iN	1.5	0.11	0.12	0.23	0.34
13	Ff1.iN	3.9	0.00	0.00	0.00	0.00
14	Fc1.lF	17.3	0.00	0.00	0.00	0.00
15	Ff2.lF	22.9	0.00	0.00	0.00	0.00
16A	Ff2.iN	1.1	0.08	0.08	0.16	0.18
16	Ff2.iN	2.4	0.00	0.00	0.00	0.00
17A	Fc2.gF	20	0.13	0.19	0.32	6.37
17	Fc2.gF	41.7	0.00	0.00	0.00	0.00
18	Fo2.lF	3.9	0.00	0.00	0.00	0.00
19A	Fc2.gS	3.5	0.13	0.08	0.21	0.75
19	Fc2.gS	3.4	0.00	0.00	0.00	0.00
20A	Fc2.gN	2.4	0.11	0.17	0.28	0.68
20	Fc2.gN	12.9	0.00	0.00	0.00	0.00
21	Ft2.tN	2.6	0.00	0.00	0.00	0.00
22A	Fc3.gF	133.9	0.06	0.01	0.07	9.71
22	Fc3.gF	27.3	0.00	0.00	0.00	0.00
23A	Fc3.gN	7.6	0.05	0.07	0.12	0.93
23	Fc3.gN	1.4	0.00	0.00	0.00	0.00
24	Gw1.lF	22.2	0.00	0.00	0.00	0.00
25	Oz3.rF	2.9	0.00	0.00	0.00	0.00
26A	Mg1.hF	82	0.13	0.12	0.25	20.77
26	Mg1.hF	13.8	0.00	0.00	0.00	0.00
27A	Mg1.lF	988.1	0.13	0.12	0.26	252.69
27	Mg1.lF	799.1	0.00	0.00	0.00	0.00
28	Mg2.mF	81.7	0.14	0.14	0.28	23.25
28A	Mg2.mF	229.2	0.00	0.00	0.00	0.00
29A	Gg1.lF	114.7	0.17	0.27	0.44	50.62
29	Gg1.lF	173.5	0.00	0.00	0.00	0.00
30	Bo3.eN	2.6	0.03	0.00	0.03	0.07
31	Ff1.tF	43.8	0.16	0.17	0.33	14.25
32	Oz2.hF	2.1	0.11	0.08	0.19	0.39
33	Ff1.lF	218.8	0.21	0.33	0.54	118.62

TOTAL AREA = 3628.9 TOTAL HABITAT UNITS = 556.32

HABITAT UNITS PER HA = 0.15

Table 9-15. Habitat availability summary- Kuntz Creek Moose

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Bc3.eN	1.7	0.03	0.04	0.07	0.11
2	Bc3.eF	0.7	0.05	0.04	0.09	0.07
3	Bc3.eS	6.3	0.08	0.04	0.12	0.76
4	Cw2.iF	6.5	0.05	0.08	0.13	0.87
5	Cw2.iS	10.5	0.08	0.08	0.16	1.68
6	Cw3.iN	139.7	0.22	0.44	0.66	92.09
7	Cw3.iS	121.7	0.17	0.27	0.44	53.48
8	Ft1.lF	102.1	0.06	0.13	0.19	19.11
9	Ff1.lF	8.5	0.08	0.19	0.27	2.30
10	Ff1.iN	13.6	0.04	0.15	0.20	2.65
11	Ft1.lS	9.4	0.08	0.12	0.20	1.88
12	Ft1.iS	15.2	0.21	0.42	0.64	9.68
13	Fc3.eN	23.3	0.11	0.22	0.33	7.69
14	Fc1.gF	0.7	0.27	0.60	0.87	0.61
15	Fc2.gN	6.8	0.17	0.40	0.56	3.84
16	Ft2.iN	9.3	0.08	0.15	0.23	2.13
17	Ft3.tN	25.7	0.24	0.41	0.65	16.59
18	Fc3.gN	70.7	0.12	0.34	0.46	32.58
19	Fc3.gS	61.1	0.12	0.13	0.25	15.12
20	Fh3.gF	81.3	0.13	0.20	0.33	27.01
21	Mg1.lF	73.3	0.08	0.18	0.26	18.80
22	Mg1.iN	30	0.05	0.18	0.24	7.10
23	Mg2.mF	122.6	0.14	0.27	0.40	49.63
24	Mg2.lS	1.5	0.08	0.24	0.32	0.48
25	Mg2.mN	170.6	0.17	0.41	0.58	98.63
26	Mg2.hN	94.2	0.20	0.48	0.68	63.86
27	Mg2.hF	188.2	0.06	0.10	0.17	31.62
28	Mg2.iS	155.3	0.08	0.08	0.16	24.85
29	Mg2.iN	21.2	0.03	0.08	0.11	2.26
30	Mg2.mS	50.8	0.08	0.08	0.16	8.13
31	Ot3.hF	2.7	0.05	0.04	0.09	0.25
32	Fl1.lF	204.9	0.15	0.24	0.39	80.48

TOTAL AREA = 1830.1   TOTAL HABITAT UNITS = 676.34

HABITAT UNITS PER HA = 0.37

9.4 BEAVER HABITAT SUITABILITY MODEL

9.4.1 Existing Models/Data bases

Sverre (1972), Todd (1978), Searing (1979), Green et al. (1984, in prep.) and Nietfeld et al. (1984) provide detailed reviews of beaver habitat requirements, incorporating data both from Alberta and from elsewhere throughout the species' range. Green et al. (1985) review habitat requirements with specific reference to the mountain and foothills biomes of the province.

Todd (1978) outlines criteria for assessing and mapping land capability for beaver production in Alberta, based on a minimum map unit size of 2.5 km^2. A biophysical model for assessing habitat suitability of homogeneous land units in Alberta (as determined from 1:500 000 scale Landsat imagery) is provided by IEC Beak (1984).

9.4.2 Major Habitat Requirements

Cover Type. Beavers require waterbodies suitable for year-round occupation, and an adjacent supply of food and building materials in the form of deciduous woods or shrublands. They occupy a variety of aquatic habitats (from ponds and small streams to large lakes and rivers), although streams appear to be most highly preferred. In Alberta, vegetation adjacent to occupied sites usually is dominated by willow, poplar or other deciduous growth.

Lodges and/or dens with entrances underwater provide the major source of escape, thermal and reproductive cover. Lodges are constructed of mud and sticks, and require an external source of building materials, whereas dens are tunneled into abrupt, stable shorelines.

Food consists primarily of willows and aspen, and secondarily of other deciduous browse. During summer, some use may be made of herbaceous terrestrial vegetation, aquatic macrophytes, and even grain crops. By contrast, conifers receive little use as either food or construction material. In most areas, a cache of woody material is constructed during fall and provides the sole or primary food source during winter, but in the Porcupine Hills region, beavers reportedly forage onshore throughout the winter period.

Slope Characteristics. Gentle to moderate slopes adjacent to waterbodies provide optimum foraging conditions, permitting easy travel over an extensive upslope area and facilitating movement of cut materials downslope. By contrast, steep slopes limit ease of movement and hence restrict potential foraging area.

Stream Permanency. Beavers require permanent standing waterbodies or a flow of water sufficient to maintain critical minimum water depths. Water provides protection from predators, ease of travel and transport of food materials, and access to lodge/den entrances. Low water levels can be tolerated to some extent during summer, but minimum depths of 0.9-1.5 m are required to permit travel beneath ice in winter. Permanent streams with stable water levels provide the best habitat, although suboptimal habitat can be improved by damming.

Floodplain Width. Wide, mesic floodplains covered by shrub growth provide the best potential beaver habitat. Beavers may forage over 200 m inland, depending on topography and forage availability, but most woody plants used for food or building materials are cut within 30 m, and only rarely beyond 100 m, of shore.

Stream Sinuosity. Beavers avoid rapidly flowing streams; low gradient, meandering streams are preferred.

9.4.3 Model Development (see Table 9-16)

General. Because of the nearly complete reliance of beavers in this region on stream habitat, the model has been designed to evaluate habitat capability of stream reaches rather than the more extensive land system polygons. This has required the use of additional variables .descriptive of stream habitat quality, and identifies variation in habitat conditions along the stream to a greater degree. Each stream reach measures 1 linear km and extends the full width of the land system comprising the stream flood plain.

It is generally bisected by the stream channel. The seasonal wetlands identified for the study sites are not considered capable of supporting beaver activity because of their seasonal nature and relatively small size, and have not been included in habitat availability estimates. Because beaver do not demonstrate seasonal shifts in habitat preferences, a year-round habitat evaluation model has been developed for this species.

Cover and food are considered of comparable significance to the survival of the beaver on a year-round basis, and have received equal weightings (0.5) in the model. Cover requirements are met largely through selection or modification (by damming) of waterbodies with adequate water supply, by construction of lodges using terrestrial vegetation, and/or through construction of bank dens. These requirements are reflected by a number of variables, the most important of which is stream permanency. Permanent streams are optimal, but intermittent streams have some value as they can be dammed. Stream sinuosity also is important, as this reflects both absolute abundance of stream habitat and velocity of water flow, while cover type determines availability of building material for lodges and dams (deciduous shrub and tree growth being considered optimal).

It is recognized that, to some degree, stream bank slopes influence the availability of building materials, with steep banks being inaccessible to beavers. However, actual bank characteristics are not discernible from the air photos used in this study, and the land systems containing each of the stream reaches are invariably rated as flat. Consequently, the "slope characteristic" variable is not incorporated into the cover submodel.

The most important variable in the food submodel is cover type, those categories providing deciduous browse being considered optimal. However, categories providing terrestrial or aquatic herbaceous vegetation also have potential value. Stream permanency is considered important in ensuring a travel route to feeding areas, but has been weighted lower than cover type. Stream sinuosity, because it reflects absolute abundance of foraging areas within a given stream reach, has been weighted comparably with stream permanency.

All stream reaches are considered to have sufficiently wide flood plains to provide adequate, accessible foraging potential, thus negating the need for "flood plain width" as a model variable. Similar to the cover submodel the "slope characteristics" variable is also excluded from the food submodel.

9.4.4 Calculation of Habitat Suitability

The following formulae were used to determine the suitability of each 1 km by 200 m stream reach as beaver habitat:

Year-long Cover Value

[0.3 x Σ (cover type rating x proportion of cover type in stream reach)] + [0.5 x stream permanency] + [0.2 x stream sinuosity]

Year-long Food Value

[0.7 x Σ (cover type rating x proportion of cover type in stream reach)] + [0.2 x stream permanency] + [0.1 x stream sinuosity]

Habitat Suitability Rating (HSR)

HSR = (0.5 x year-round cover) + (0.5 x year-round food)

Habitat Suitability Index (HSI)

HSI = HSR/3

Table: 9-16 Willow Creek Wildlife Capability Model - Beaver

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Year/ Long	0.5	Cover	0.3	Cover type	0	-bare soil/rock
					0	-seasonal wetland
					2	-permanent wetland/ open water
					0	-native grassland
					0	-improved pasture
					0	-cropland
					2	-shrub meadow (10-50% shrub cover)
					3	-shrubland (>50% shrub cover)
					1	-conifer parkland (10-50% tree cover)
					2	-deciduous parkland
					1	-conifer forest (>50% tree cover)
					3	-deciduous forest (>50% tree cover)
					3	-mixed forest (>50% tree cover)
			N/A	Slope characteristics		-steep, broken (>30° slopes predominate)
						-moderate, rolling (10-30°)
						-flat (<10°)
			N/A	Major aspects		-cool slopes (W-N-SE)
						-warm slopes (SE-S-W)
						-flat
			0.5	Stream permanency	1	-intermittent
					3	-permanent
			0.2	Stream sinuosity	1	-straight
					2	-curved
					3	-meandering

Table: 9-16 (cont'd) Willow Creek Wildlife Capability Model - Beaver

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Year/ Long	0.5	Food	0.7	Cover type	0	-bare soil/rock
					0	-seasonal wetland
					1	-permanent wetland/ open water
					0	-native grassland
					0	-improved pasture
					0	-cropland
					2	-shrub meadow (10-50% shrub cover)
					3	-shrubland (>50% shrub cover)
					1	-conifer parkland (10-50% tree cover)
					2	-deciduous parkland
					1	-conifer forest (>50% tree cover)
					3	-deciduous forest (>50% tree cover)
					2	-mixed forest (>50% tree cover)
			N/A	Slope characteristics		-steep, broken (>30° slopes predominate)
						-moderate, rolling (10-30°)
						-flat (<10°)
			N/A	Major aspects		-cool slopes (W-N-SE)
						-warm slopes (SE-S-W)
						-flat
			0.2	Stream permanency	1	-intermittent
					3	-permanent
			0.1	Stream sinuosity	1	-straight
					2	-curved
					3	-meandering

Table 9-17. Habitat availability summary -Willow Creek Beaver

REACH NUMBER	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	19.6	0.47	0.31	0.78	15.35
2	57.9	0.44	0.35	0.79	45.55
3	34.6	0.43	0.35	0.79	27.17
4	45	0.38	0.22	0.60	26.94
5	23.2	0.39	0.24	0.63	14.50
6	31.2	0.42	0.31	0.73	22.62
7	46.5	0.38	0.26	0.64	29.90
8	32.1	0.38	0.23	0.61	19.58
9	43	0.41	0.29	0.70	29.89

TOTAL AREA = 333.1

TOTAL HABITAT UNITS = 231.49

HABITAT UNITS PER HA= 0.69

Table 9-18. Habitat availability summary- Pine Coulee (Site 2) Beaver

REACH NUMBER	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	17.5	0.27	0.28	0.54	9.50
2	17.6	0.18	0.00	0.18	3.23
3	20.2	0.13	0.03	0.16	3.14
4	12.4	0.23	0.26	0.49	6.10
5	18.8	0.20	0.28	0.48	9.04
6	22.6	0.20	0.29	0.50	11.25
7	22.5	0.22	0.25	0.47	10.54
8	24.4	0.24	0.19	0.43	10.50
9	13.7	0.15	0.00	0.15	2.06
10	10.2	0.23	0.25	0.48	4.85
11	8.7	0.22	0.33	0.55	4.79
12	17.1	0.28	0.33	0.62	10.55
13	33.4	0.18	0.08	0.26	8.63
14	34	0.18	0.00	0.18	6.23
15	15.1	0.12	0.00	0.12	1.76

TOTAL AREA = 288.2

TOTAL HABITAT UNITS = 102.16

HABITAT UNITS PER HA = 0.35

Table 9-19. Habitat availability summary - Pine Coulee (Site 4) Beaver

REACH NUMBER	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	17.5	0.27	0.28	0.54	9.50
2	17.6	0.18	0.00	0.18	3.23
3	20.2	0.13	0.03	0.16	3.14
4	12.4	0.23	0.26	0.49	6.10
5	18.8	0.20	0.28	0.48	9.04
6	22.6	0.20	0.29	0.50	11.25
7	22.5	0.22	0.25	0.47	10.54
8	24.4	0.24	0.19	0.43	10.50
9	13.7	0.15	0.00	0.15	2.06
10	10.2	0.23	0.25	0.48	4.85
11	8.7	0.22	0.33	0.55	4.79
12	17.1	0.28	0.33	0.62	10.55
13	33.4	0.18	0.08	0.26	8.63
14	34	0.18	0.00	0.18	6.23
15	15.1	0.12	0.00	0.12	1.76
16	42.9	0.21	0.09	0.30	12.88
17	19.3	0.17	0.07	0.24	4.69
18	20.8	0.27	0.27	0.54	11.20
19	38.8	0.31	0.44	0.75	29.14
20	27.8	0.21	0.19	0.39	10.86
21	69.1	0.23	0.28	0.51	35.07

TOTAL AREA= 506.9 TOTAL HABITAT UNITS = 206.01

HABITAT UNITS PER HA =. 0.41

Table 9-20. Habitat availability summary- Kuntz Creek Beaver

REACH NUMBER	TOTAL AREA	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	8.1	0.47	0.48	0.95	7.70
2	8.3	0.47	0.48	0.95	7.89
3	12.6	0.50	0.50	1.00	12.60
4	72	0.37	0.21	0.58	41.76
5	38.7	0.37	0.19	0.55	21.29
6	17.8	0.45	0.38	0.84	14.86
7	12	0.44	0.42	0.87	10.38
8	9.4	0.39	0.30	0.69	6.44
9	11	0.41	0.34	0.75	8.20
10	6.4	0.36	0.23	0.59	3.74
11	8.6	0.47	0.48	0.95	8.17

TOTAL AREA = 204.9 TOTAL HABITAT UNITS = 146.48

HABITAT UNITS PER HA = 0.70

9.5 SNOWSHOE HARE HABITAT SUITABILITY MODEL

9.5.1 Existing Models/Data bases

Habitat requirements of snowshoe hares have been reviewed with particular reference to Alberta by Green (1979) and Green et al. (1984, 1985). No biophysical models specific to Alberta have been developed, but a habitat model based largely on data from Alaska is available (USFWS 1980).

9.5.2 Major Habitat Requirements

Snowshoe hares are found in a variety of woody vegetation types, including deciduous forests, coniferous forests, mixed forest, bogs and shrublands. The key habitat feature is a dense shrub layer, which provides hiding, reproductive and thermal cover as well as food. Habitat patchiness or interspersion also is important, with openings adjacent to dense cover providing an additional food source.

Snowshoe hares are opportunistic feeders. In general their diet consists of grasses, forbes and browse during spring/summer, and both hardwood and conifer browse during winter.

9.5.3 Model Development (see Table 9-21)

Habitat use by snowshoe hares does not vary greatly through the year, and therefore a general model covering all seasons was developed.

Cover availability is considered to be the critical habitat feature for this species. In addition, areas providing suitable cover also provide much of the food supply, particularly during winter. The cover submodel is therefore given a heavier weighting (0.7) than is the food submodel (0.3).

Cover availability can be described completely by vegetation (cover) type, and this is the only variable included in the cover submodel. Only categories potentially providing a dense shrub and/or tree layer are considered to provide suitable cover.

Similarly, food availability can be described completely by vegetation type. Shrublands and forests are assumed to provide an optimal mix of browse and herbaceous food plants and are given the highest ratings, but open herbaceous areas also have potential foraging value when adjacent to dense cover.

9.5.4 Calculation of Habitat Suitability

The following formulae were used to determine the suitability of each land system polygon as snowshoe hare habitat:

Year-long Cover Value

[1.0 x Σ(cover type rating x proportion of cover type in land system)]

Year-long Food Value

[1.0 x Σ(cover type rating x proportion of cover type in land system)]

Habitat Suitability Rating (HSR)

HSR = (0.7 x year-long cover) + (0.3 x year-long food)

Habitat Suitability Index (HSI)

HSI = HSR/3

Table: 9-21 Willow Creek Wildlife Capability Model - Snowshoe Hare

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Year-long	0.7	Cover	1.0	Cover type	0	-bare soil/rock
					0	-seasonal wetland
					1	-permanent wetland/ open water
					0	-native grassland
					0	-improved pasture
					0	-cropland
					2	-shrub meadow (10-50% shrub cover)
					3	-shrubland (>50% shrub cover)
					2	-conifer parkland (10-50% tree cover)
					2	-deciduous parkland
					3	-conifer forest (>50% tree cover)
					3	-deciduous forest (>50% tree cover)
					3	-mixed forest (>50% tree cover)
			N/A	Slope characteristics		-steep, broken (>30° slopes predominate)
						-moderate, rolling (10-30°)
						-flat (<10°)
			N/A	Major aspects		-cool slopes (W-N-SE)
						-warm slopes (SE-S-W)
						-flat
			N/A	Stream permanency		-intermittent
						-permanent
			N/A	Stream sinuosity		-straight
						-curved
						-meandering

Table: 9-21 Willow Creek Wildlife Capability Model - Snowshoe Hare

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Year-long	0.3	Food	1.0	Cover type	0	-bare soil/rock
					1	-seasonal wetland
					2	-permanent wetland/ open water
					1	-native grassland
					1	-improved pasture
					1	-cropland
					2	-shrub meadow (10-50% shrub cover)
					3	-shrubland (>50% shrub cover)
					2	-conifer parkland (10-50% tree cover)
					2	-deciduous parkland
					3	-conifer forest (>50% tree cover)
					3	-deciduous forest (>50% tree cover)
					3	-mixed forest (>50% tree cover)
			N/A	Slope characteristics		-steep, broken (>30° slopes predominate)
						-moderate, rolling (10-30°)
						-flat (<10°)
			N/A	Major aspects		-cool slopes (W-N-SE)
						-warm slopes (SE-S-W)
						-flat
			N/A	Stream permanency		-intermittent
						-permanent
			N/A	Stream sinuosity		-straight
						-curved
						-meandering

Table 9-22. Habitat availability summary- Willow Creek Snowshoe Hare

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Fl1.lF	333.1	0.27	0.16	0.42	140.24
2	Cw2.tS	10	0.00	0.10	0.10	1.00
3	Cw3.eS	3.8	0.00	0.00	0.00	0.00
4	Fc3.eF	6.5	0.00	0.10	0.10	0.65
5	Fc2.eF	20.6	0.00	0.10	0.10	2.06
6	Bo3.iN	5.7	0.00	0.00	0.00	0.00
7	Mg1.lF	1340	0.01	0.05	0.05	72.36
8	Fo2.lF	3.1	0.00	0.07	0.07	0.21
9	Fc1.eF	0.6	0.00	0.10	0.10	0.06
10	Cw2.iN	15.9	0.07	0.12	0.19	3.02
11	Mg3.rF	5.6	0.00	0.10	0.10	0.56
12	Cw2.iS	1.6	0.00	0.10	0.10	0.16
13	Mg2.vF	6.1	0.00	0.10	0.10	0.61
14	Bo3.eS	21.7	0.00	0.00	0.00	0.00
15	Bo3.fS	1.7	0.00	0.00	0.00	0.00
16	Fw2.iS	34.3	0.00	0.09	0.09	3.16
17	Fc2.eS	1.4	0.00	0.10	0.10	0.14
18	Cw3.iS	13.2	0.00	0.10	0.10	1.32
19	Fw2.tS	43.2	0.00	0.10	0.11	4.65
20	Cw3.lS	4.1	0.00	0.10	0.10	0.41
21	Cw3.iN	29.2	0.70	0.30	1.00	29.20
22	Mw2.mF	3.4	0.00	0.10	0.10	0.34
23	Fc1.gF	4.7	0.70	0.30	1.00	4.70

TOTAL AREA = 1910.5

TOTAL UNITS = 264.84

UNITS PER HA = 0.14

Table 9-23. Habitat availability summary - Pine Coulee (Site 2) Snowshoe Hare

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Bo3.eS	2.7	0.00	0.00	0.00	0.00
2	Bo3.lF	0.5	0.00	0.00	0.00	0.00
3	Cw2.iS	76.3	0.05	0.11	0.16	12.13
4	Cw2.iN	126.2	0.07	0.12	0.19	23.98
5	Cw1.iN	24.7	0.00	0.10	0.10	2.47
6	Cw2.tN	67	0.12	0.13	0.25	16.97
7	Cw3.iS	76.9	0.00	0.10	0.10	7.69
8	Cw3.eS	0.8	0.00	0.00	0.00	0.00
9	Cw3.iN	39.5	0.43	0.17	0.59	23.48
10	Cw3.cN	10.5	0.70	0.30	1.00	10.50
11	Ff1.iS	5.1	0.00	0.10	0.10	0.51
12	Ff1.lF	3.5	0.00	0.10	0.10	0.35
13	Ff1.iN	5.4	0.00	0.10	0.10	0.54
14	Fc1.lF	17.3	0.00	0.10	0.10	1.73
15	Ff2.lF	22.9	0.00	0.09	0.09	2.15
16	Ff2.iN	3.5	0.00	0.10	0.10	0.35
17	Fc2.cF	54.8	0.27	0.17	0.44	24.09
18	Fc2.iF	3.9	0.00	0.10	0.10	0.39
19	Fc2.cS	6.9	0.00	0.10	0.10	0.69
20	Fc2.cN	15.3	0.11	0.13	0.24	3.73
21	Ft2.tN	2.6	0.00	0.10	0.10	0.26
22	Fc3.cF	27.3	0.02	0.11	0.13	3.47
23	Fc3.cN	9	0.09	0.13	0.22	1.95
24	Gw1.lF	22.2	0.03	0.10	0.13	2.91
25	Oz3.rF	2.9	0.00	0.00	0.00	0.00
26	Mg1.hF	95.8	0.00	0.10	0.10	9.58
27	Mg1.lF	1611.5	0.00	0.10	0.11	171.89
28	Mg2.mF	81.7	0.03	0.11	0.14	11.71
29	Gg1.lF	288.2	0.22	0.15	0.37	105.58

TOTAL AREA= 2704.9 TOTAL HABITAT UNITS= 439.11

HABITAT UNITS PER HA = 0.16

Table 9-24. Habitat availability summary- Pine Coulee (Site 4) Snowshoe Hare

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Bo3.eS	14	0.00	0.00	0.00	0.00
2	Bo3.lF	0.5	0.00	0.00	0.00	0.00
3	Cw2.iS	86.1	0.04	0.11	0.15	13.20
4	Cw2.iN	165.6	0.05	0.11	0.17	27.38
5	Cw1.iN	24.7	0.00	0.10	0.10	2.47
6	Cw2.tN	67	0.12	0.13	0.25	16.97
7	Cw3.iS	98.2	0.00	0.10	0.10	9.53
8	Cw3.eS	3.5	0.00	0.00	0.00	0.00
9	Cw3.iN	51.8	0.34	0.15	0.49	25.23
10	Cw3.cN	10.5	0.70	0.30	1.00	10.50
11	Ff1.iS	5.1	0.00	0.10	0.10	0.51
12	Ff1.lF	18.9	0.00	0.02	0.02	0.36
13	Ff1.iN	5.4	0.00	0.10	0.10	0.54
14	Fc1.lF	17.3	0.00	0.10	0.10	1.73
15	Ff2.lF	22.9	0.00	0.09	0.09	2.15
16	Ff2.iN	3.5	0.00	0.10	0.10	0.35
17	Fc2.cF	61.4	0.24	0.16	0.40	24.85
18	Fc2.iF	3.9	0.00	0.10	0.10	0.39
19	Fc2.cS	6.9	0.00	0.10	0.10	0.69
20	Fc2.cN	15.3	0.11	0.13	0.24	3.73
21	Ft2.tN	2.6	0.00	0.10	0.10	0.26
22	Fc3.cF	152.7	0.01	0.10	0.11	17.10
23	Fc3.cN	9	0.09	0.13	0.22	1.95
24	Gw1.lF	22.2	0.03	0.10	0.13	2.91
25	Oz3.rF	2.9	0.00	0.00	0.00	0.00
26	Mg1.hF	95.8	0.00	0.10	0.10	9.58
27	Mg1.lF	1794.6	0.00	0.10	0.10	183.65
28	Mg2.mF	311.1	0.01	0.10	0.11	33.60
29	Gg1.lF	288.2	0.22	0.15	0.37	105.58
30	Bo3.eN	2.6	0.00	0.00	0.00	0.00
31	Ff1.tF	43.8	0.07	0.12	0.19	8.32
32	Oz2.hF	2.1	0.00	0.00	0.00	0.00
33	Ff1.lF	218.8	0.34	0.19	0.53	115.16

TOTAL AREA = 3628.9 TOTAL HABITAT UNITS = 618.69

HABITAT UNITS PER HA = 0.17

Table 9-25. Habitat avaiability summary- Kuntz Creek Snowshoe Hare

SYSTEM NUMBER	LAND SYSTEM	TOTAL AREA	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Bc3.eN	1.7	0	0	0	0
2	Bc3.eF	0.7	0	0	0	0
3	Bc3.eS	6.3	0	0	0	0
4	Cw2.iF	6.5	0	0	0	0
5	Cw2.iS	10.5	0	0	0	0
6	Cw3.iN	139.7	0.651	0.285	0.936	130.76
7	Cw3.iS	121.7	0.322	0.185	0.507	61.702
8	Ft1.lF	102.1	0.014	0.103	0.117	11.946
9	Ff1.lF	8.5	0.098	0.128	0.226	1.921
10	Ff1.iN	13.6	0.049	0.114	0.163	2.2168
11	Ft1.lS	9.4	0	0.1	0.1	0.94
12	Ft1.iS	15.2	0.441	0.226	0.667	10.138
13	Fc3.eN	23.3	0.266	0.176	0.442	10.299
14	Fc1.gF	0.7	0.7	0.3	1	0.7
15	Fc2.gN	6.8	0.462	0.232	0.694	4.7192
16	Ft2.iN	9.3	0.161	0.146	0.307	2.8551
17	Ft3.tN	25.7	0.539	0.296	0.835	21.46
18	Fc3.gN	70.7	0.4573	0.211	0.6683	47.251
19	Fc3.gS	61.1	0.133	0.137	0.27	16.497
20	Fh3.gF	81.3	0.259	0.171	0.43	34.959
21	Mg1.lF	73.3	0.084	0.124	0.208	15.246
22	Mg1.iN	30	0.091	0.126	0.217	6.51
23	Mg2.mF	122.6	0.2917	0.182	0.4737	58.072
24	Mg2.lS	1.5	0	0.1	0.1	0.15
25	Mg2.mN	170.6	0.476	0.237	0.713	121.64
26	Mg2.hN	94.2	0.5763	0.265	0.8413	79.254
27	Mg2.hF	188.2	0.035	0.111	0.146	27.477
28	Mg2.iS	155.3	0	0.1	0.1	15.53
29	Mg2.iN	21.2	0	0	0	0
30	Mg2.mS	50.8	0	0	0	0
31	Ot3.hF	2.7	0	0	0	0
32	Fl1.lF	204.9	0.2987	0.178	0.4767	97.669

TOTAL AREA = 1830.1 TOTAL HABITAT UNITS = 779.91

HABITAT UNITS PER HA= 0.43

9.6 RING-NECKED PHEASANT HABITAT SUITABILITY MODEL

9.6.1 Existing Models/Data bases

Habitat requirements of ring-necked pheasants in Alberta are reviewed by Vriend and Barrett (1978), Green et al. (1984, in prep.) and Nietfeld et al. (1984). IEC Beak (1984) outlines a biophysical model for rating capability of land units for pheasant production throughout the province.

9.6.2 Major Habitat Requirements

Cover Type. In Alberta, ring-necked pheasants are strongly associated with the agricultural zone, and within this region with herbaceous and shrub vegetation. Dense, residual herbaceous and shrub growth in and around sloughs, drainage ditches, creek bottoms and coulees provides ideal nesting sites and brood-rearing cover, and year-round travel lanes, escape cover and thermal cover. Adjacent agricultural fields and haylands also provide major reproductive cover, potential winter cover and a year-long food source. Extensive woodlands are little used for either food or cover, but during severe winter conditions pheasants seek multi-layered, closed canopy woody growth, such as is found in shelterbelts and around forest edges. Availability of dense herbaceous and/or low woody vegetation is thus a critical feature of winter habitat.

Pheasants feed primarily in croplands and other herbaceous vegetation year-long, making relatively little use of woody vegetation types. Farm crops are used more heavily than is native vegetation, and as a result food availability is rarely limiting, even during winter.

9.6.3 Model Development (see Table 9-26)

Seasonal habitat requirements of pheasants are not identical but do overlap extensively, and occupied areas generally provide winter cover, nesting sites and feeding areas all in proximity. A generalized year-long model was therefore considered more appropriate for this species than separate seasonal models.

The critical requirement of pheasant habitat is suitable cover. Because habitat appears to be selected on the basis of suitable cover adjacent to feeding areas, rather than *vice versa*, because escape/thermal cover also is often used for feeding, and because food usually is abundant, whereas cover may be limiting, the cover submodel is given a higher weighting (0.7) than is the food submodel (0.3).

Of the biophysical variables used in this study, cover type best describes availability of reproductive, escape and thermal cover. Highest ratings are assigned to categories used year-long and providing optimum conditions (i.e., herbaceous and herbaceous/shrub vegetation), and progressively lower ratings are given to categories receiving less or no use (i.e., increasingly treed vegetation and bare soil/rock).

As with cover, food availability is best predicted by vegetation or cover type. Categories are ranked according to their potential for providing a cultivated seed crop or other herbaceous food source. The stream permanency variable also is included in the model, as land systems with a permanent water source are considered to have enhanced capability for use by pheasants.

9.6.4 Calculation of Habitat Suitability

The following formulae were used to determine the suitability of each land system polygon as ring-necked pheasant habitat:

Year-long Cover Value

[1.0 x Σ(cover type rating x proportion of cover type in land system)]

Year-long Food Value

[0.8 x Σ(cover type rating x proportion of cover type in land system)]
+ [0.2 x stream permanency]

Habitat Suitability Rating (HSR)

HSR = (0.7 x year-long cover) + (0.3 x year-long food)

Habitat Suitability Index (HSI)

HSI = HSR/3

Table: 9-26 Willow Creek Wildlife Capability Model - Ringed-necked Pheasant

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Year-long	0.7	Cover	1.0	Cover type	0	-bare soil/rock
					1	-seasonal wetland
					3	-permanent wetland/ open water
					1	-native grassland
					2	-improved pasture
					2	-cropland
					3	-shrub meadow (10-50% shrub cover)
					3	-shrubland (>50% shrub cover)
					2	-conifer parkland (10-50% tree cover)
					2	-deciduous parkland
					1	-conifer forest (>50% tree cover)
					1	-deciduous forest (>50% tree cover)
					1	-mixed forest (>50% tree cover)
			N/A	Slope characteristics		-steep, broken (>30° slopes predominate)
						-moderate, rolling (10-30°)
						-flat (<10°)
			N/A	Major aspects		-cool slopes (W-N-SE)
						-warm slopes (SE-S-W)
						-flat
			N/A	Stream permanency		-intermittent
						- permanent
			N/A	Stream sinuosity		-straight
						-curved
						-meandering

Table: 9-26 (Cont'd) Willow Creek Wildlife Capability Model - Ringed-necked Pheasant

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Year-long	0.3	Food	0.8	Cover type	0	-bare soil/rock
					2	-seasonal wetland
					3	-permanent wetland/ open water
					2	-native grassland
					2	-improved pasture
					3	-cropland
					2	-shrub meadow (10-50% shrub cover)
					1	-shrubland (>50% shrub cover)
					1	-conifer parkland (10-50% tree cover)
					1	-deciduous parkland
					1	-conifer forest (>50% tree cover)
					1	-deciduous forest (>50% tree cover)
					1	-mixed forest (>50% tree cover)
			N/A	Slope characteristics		-steep, broken (>30° slopes predominate)
						-moderate, rolling (10-30°)
						-flat (<10°)
			N/A	Major aspects		-cool slopes (W-N-SE)
						-warm slopes (SE-S-W)
						-flat
			0.2	Stream permanency	1	-intermittent
					3	-permanent
			N/A	Stream sinuosity		-straight
						-curved
						-meandering

Table 9-27. Habitat availability summary- Willow Creek Ring-necked Pheasant

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Fl1.lF	333.1	0.31	0.17	0.47	157.51
2	Cw2.tS	10	0.23	0.16	0.39	3.93
3	Cw3.eS	3.8	0.00	0.00	0.00	0.00
4	Fc3.eF	6.5	0.23	0.16	0.39	2.56
5	Fc2.eF	20.6	0.23	0.15	0.38	7.87
6	Bo3.iN	5.7	0.00	0.00	0.00	0.00
7	Mg1.lF	1340	0.43	0.20	0.63	850.72
8	Fc2.lF	3.1	0.16	0.11	0.27	0.83
9	Fc1.eF	0.6	0.23	0.16	0.39	0.24
10	Cw2.iN	15.9	0.23	0.15	0.39	6.13
11	Mg3.rF	5.6	0.23	0.16	0.39	2.20
12	Cw2.iS	1.6	0.23	0.16	0.39	0.63
13	Mg2.vF	6.1	0.23	0.24	0.47	2.89
14	Bo3.eS	21.7	0.23	0.00	0.23	5.06
15	Bo3.iS	1.7	0.00	0.00	0.00	0.00
16	Fw2.iS	34.3	0.21	0.15	0.36	12.41
17	Fc2.eS	1.4	0.23	0.16	0.39	0.55
18	Cw3.iS	13.2	0.23	0.16	0.39	5.19
19	Fw2.tS	43.2	0.24	0.16	0.40	17.13
20	Cw3.lS	4.1	0.23	0.16	0.39	1.61
21	Cw3.iN	29.2	0.70	0.08	0.78	22.78
22	Mw2.mF	3.4	0.34	0.20	0.53	1.81
23	Fc1.gF	4.7	0.70	0.08	0.78	3.67

TOTAL AREA = 1910.5 TOTAL HABITAT UNITS = 1105.70

HABITAT UNITS PER HA = 0.58

Table 9-28. Habitat availability summary- Pine Coulee (Site 2) Ring-necked Pheasant

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Bo3.eS	2.7	0.00	0.00	0.00	0.00
2	Bo3.lF	0.5	0.00	0.00	0.00	0.00
3	Cw2.iS	76.3	0.31	0.16	0.47	35.53
4	Cw2.iN	126.2	0.42	0.16	0.58	73.00
5	Cw1.iN	24.7	0.47	0.16	0.63	15.48
6	Cw2.tN	67	0.42	0.15	0.57	38.37
7	Cw3.iS	76.9	0.24	0.16	0.40	30.61
8	Cw3.eS	0.8	0.00	0.00	0.00	0.00
9	Cw3.iN	39.5	0.59	0.14	0.73	28.69
10	Cw3.cN	10.5	0.70	0.08	0.78	8.19
11	Ff1.iS	5.1	0.23	0.16	0.39	2.01
12	Ff1.lF	3.5	0.23	0.16	0.39	1.38
13	Ff1.iN	5.4	0.40	0.16	0.56	3.03
14	Fc1.lF	17.3	0.47	0.19	0.66	11.38
15	Ff2.lF	22.9	0.44	0.15	0.59	13.49
16	Ff2.iN	3.5	0.47	0.16	0.63	2.19
17	Fo2.GF	54.8	0.35	0.14	0.50	27.16
18	Fc2.iF	3.9	0.23	0.16	0.39	1.53
19	Fc2.cS	6.9	0.23	0.16	0.39	2.71
20	Fc2.cN	15.3	0.36	0.15	0.51	7.75
21	Ft2.tN	2.6	0.23	0.16	0.39	1.02
22	Fc3.cF	27.3	0.25	0.16	0.40	11.05
23	Fc3.cN	9	0.29	0.15	0.44	3.99
24	Gw1.lF	22.2	0.43	0.20	0.64	14.16
25	Oz3.rF	2.9	0.00	0.00	0.00	0.00
26	Mg1.hF	95.8	0.47	0.18	0.65	62.03
27	Mg1.lF	1611.5	0.44	0.20	0.64	1036.84
28	Mg2.mF	81.7	0.30	0.17	0.47	38.13
29	Gg1.lF	288.2	0.50	0.17	0.67	193.27

TOTAL AREA= 2704.9

TOTAL HABITAT UNITS= 1663.00

HABITAT UNITS PER HA = 0.61

Table 9-29. Habitat availability summary - Pine Coulee (Site 4) Ring-necked Pheasant

SYSTEM NUMBER	LAND SYSTEM	AREA (HA)	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Bo3.eS	14	0.00	0.00	0.00	0.00
2	Bo3.lF	0.5	0.00	0.00	0.00	0.00
3	Cw2.iS	86.1	0.30	0.16	0.46	39.49
4	Cw2.iN	165.6	0.47	0.19	0.66	109.31
5	Cw1.iN	24.7	0.47	0.16	0.63	15.48
6	Cw2.tN	67	0.42	0.15	0.57	38.37
7	Cw3.iS	98.2	0.23	0.16	0.38	37.70
8	Cw3.eS	3.5	0.00	0.00	0.00	0.00
9	Cw3.iN	51.8	0.51	0.14	0.64	33.36
10	Cw3.gN	10.5	0.70	0.08	0.78	8.19
11	Ff1.iS	5.1	0.23	0.16	0.39	2.01
12	Ff1.lF	18.9	0.61	0.16	0.77	14.58
13	Ff1.iN	5.4	0.40	0.16	0.56	3.03
14	Fo1.lF	17.3	0.47	0.19	0.66	11.38
15	Ff2.lF	22.9	0.44	0.15	0.59	13.49
16	Ff2.iN	3.5	0.47	0.16	0.63	2.19
17	Fc2.gF	61.4	0.34	0.14	0.48	29.66
18	Fc2.iF	3.9	0.23	0.16	0.39	1.53
19	Fc2.cS	6.9	0.23	0.16	0.39	2.71
20	Fc2.cN	15.3	0.36	0.15	0.51	7.75
21	Ft2.tN	2.6	0.23	0.16	0.39	1.02
22	Fc3.gF	152.7	0.25	0.16	0.41	61.95
23	Fc3.cN	9	0.29	0.15	0.44	3.99
24	Gw1.lF	22.2	0.43	0.20	0.64	14.16
25	Oz3.rF	2.9	0.00	0.00	0.00	0.00
26	Mg1.hF	95.8	0.47	0.18	0.65	62.03
27	Mg1.lF	1794.6	0.43	0.20	0.63	1130.60
28	Mg2.mF	311.1	0.30	0.16	0.46	143.17
29	Gg1.lF	288.2	0.50	0.17	0.67	193.27
30	Bo3.eN	2.6	0.00	0.00	0.00	0.00
31	Ff1.tF	43.8	0.49	0.15	0.64	28.12
32	Oz2.hF	2.1	0.00	0.00	0.00	0.00
33	Ff1.lF	218.8	0.49	0.12	0.61	134.52

TOTAL AREA = 3628.9 TOTAL HABITAT UNITS = 2143.05

HABITAT UNITS PER HA = 0.59

Table 9-30. Habitat availability summary- Kuntz Creek Ring-necked Pheasant

SYSTEM NUMBER	LAND SYSTEM	TOTAL AREA	HSI COVER	HSI FOOD	HSI TOTAL	HABITAT UNITS
1	Bc3.eN	1.7	0.00	0.00	0.00	0.00
2	Bc3.eF	0.7	0.00	0.00	0.00	0.00
3	Bc3.eS	6.3	0.00	0.00	0.00	0.00
4	Cw2.iF	6.5	0.00	0.00	0.00	0.00
5	Cw2.iS	10.5	0.00	0.00	0.00	0.00
6	Cw3.iN	139.7	0.26	0.04	0.31	42.65
7	Cw3.iS	121.7	0.44	0.17	0.61	74.59
8	Ft1.lF	102.1	0.41	0.16	0.57	57.78
9	Ff1.lF	8.5	0.43	0.15	0.58	4.95
10	Ff1.iN	13.6	0.23	0.15	0.39	5.27
11	Ft1.lS	9.4	0.47	0.16	0.63	5.89
12	Ft1.iS	15.2	0.53	0.11	0.64	9.68
13	Fc3.eN	23.3	0.41	0.13	0.54	12.59
14	Fc1.gF	0.7	0.23	0.08	0.31	0.22
15	Fc2.gN	6.8	0.28	0.11	0.38	2.60
16	Ft2.iN	9.3	0.23	0.12	0.36	3.32
17	Ft3.tN	25.7	0.53	0.12	0.64	16.51
18	Fc3.gN	70.7	0.51	0.09	0.59	41.91
19	Fc3.gS	61.1	0.28	0.15	0.42	25.96
20	Fh3.gF	81.3	0.37	0.12	0.49	40.11
21	Mg1.lF	73.3	0.29	0.15	0.44	32.23
22	Mg1.iN	30	0.31	0.15	0.46	13.66
23	Mg2.mF	122.6	0.40	0.13	0.53	65.39
24	Mg2.lS	1.5	0.23	0.16	0.39	0.59
25	Mg2.mN	170.6	0.55	0.11	0.66	111.83
26	Mg2.hN	94.2	0.61	0.09	0.70	65.89
27	Mg2.hF	188.2	0.25	0.16	0.41	76.65
28	Mg2.iS	155.3	0.23	0.16	0.39	61.08
29	Mg2.iN	21.2	0.00	0.00	0.00	0.00
30	Mg2.mS	50.8	0.00	0.02	0.02	1.02
31	Ot3.hF	2.7	0.00	0.00	0.00	0.00
32	Fl1.lF	204.9	0.45	0.14	0.59	121.60

TOTAL AREA = 1830.1 TOTAL HABITAT UNITS= 893.99

HABITAT UNITS PER HA = 0.49

9.7 MALLARD HABITAT SUITABILITY MODEL

9.7.1 Existing Models/Data bases

Habitat requirements of mallards have been reviewed, with special reference to Alberta conditions, by Green et al. (1984, in prep.).

9.7.2 Major Habitat Requirements

The mallard is a highly adaptable species, utilizing sloughs, ponds, lakes, backwaters of rivers and streams, and seasonally flooded areas. The best spring habitat (breeding through early brood-rearing) is provided by seasonal wetland complexes with an interspersion of dense herbaceous growth and open water areas. Nesting occurs primarily in upland habitat offering dense herbaceous cover, often far from water. Larger, permanent waterbodies are important later in the season for both brood-rearing and moulting.

Food is obtained from a variety of wetland and terrestrial habitats, from highly productive sheetwater (ephemeral) wetlands to grainfields. Adults feed chiefly on seeds of aquatic and emergent plants throughout spring and summer. Ducklings initially feed almost exclusively on invertebrates, but plant material becomes progressively more important as the birds get older. Feeding in old stubble fields may occur in early spring, but most foraging on upland crops takes place during late summer and early fall.

9.7.3 Model Development (see Table 9-31)

Although mallards will use terrestrial land systems for foraging and cover, they do have a strong requirement for open water. Consequently, the models below have been designed to assess habitat capability of seasonal wetlands and stream reaches rather than the more extensive land system polygons. Similar to the beaver model, each stream reach evaluated measures 1 linear km and extends the full width of the land system comprising the stream flood plain.

General. In order to account for seasonal variation in habitat selection two models were developed, one covering the spring period (breeding, nesting and early brood-rearing), and the second covering summer/fall (late brood-rearing, moulting, migration staging). Because annual mallard production is strongly related to availability of suitable reproductive habitat early in the season, the spring period has been weighted more heavily (0.7) than summer/fall (0.3).

Spring. The spring model assumes that potential food sources are abundant and widespread, whereas adequate wetland cover is likely to be limited. The cover submodel has consequently been given a heavier weighting (0.7) than the food submodel (0.3).

Spring cover for mallards is provided almost entirely by dense herbaceous vegetation, the availability of which is best predicted by the cover type variable. Vegetation associated with wetlands is considered optimal but other cover types potentially providing herbaceous cover also have some value. Stream sinuosity is included in the submodel because it reflects the absolute abundance of stream habitat. Land systems with permanent streams are considered to have greater capability for mallard production than those with an intermittent stream.

Variables and variable categories in the food submodel are rated primarily on the basis of potential for providing wetland foraging habitat, and secondarily on the basis of provision of upland seed crops. As in the cover submodel, this potential is best reflected by cover type, but stream permanency and stream sinuosity also influence development of wetlands and hence extent of wetland vegetation.

Summer/Fall. Throughout most of summer and fall food and cover are provided primarily by permanent wetlands. The loss of seasonal wetlands as a food source is partially balanced by the availability of ripening seed crops, but there also are additional energetic demands related to the moult and premigration fattening.

Food and cover are therefore given equal weightings in the summer/fall model.

Permanent wetlands are considered to be virtually the only cover type suitable for occupation during this period, although some seasonal wetlands may still be available. The availability of permanent stream habitat becomes increasingly important during summer/fall relative to spring. Topography and stream sinuosity are included in the cover submodel to account for their presumed effects on extent of wetland development.

The presence of permanent wetlands and croplands within a land system polygon are the main determinants of food availablility during summer/fall, although other herbaceous vegetation types also may have some value as foraging habitat. As in the spring food submodel, stream permanency and stream sinuosity are considered to reflect wetland development and are therefore included as minor variables.

9.7.4 Calculation of Habitat Suitability

The following formulae were used to determine the suitability of each land system polygon as mallard habitat:

Spring Cover Value

[0.6 x Σ(cover type rating x proportion of cover type in land system)] + [0.3 x stream permanency] + [0.1 x stream sinuosity]

Spring Food Value

[0.6 x Σ(cover type rating x proportion of cover type in land system)] + [0.3 x stream permanency] + [0.1 x stream sinuosity]

Summer/Fall Cover Value

[0.4 x Σ(cover type rating x proportion of cover type in land system)] + [0.4 x stream permanency] + [0.2 x stream sinuosity]

Summer/Fall Food Value

[0.6 x Σ(cover type rating x proportion of cover type in land system)] + [0.2 x stream permanency] + [0.2 x stream sinuosity]

Habitat Suitability Rating (HSR)

HSR (Spring) = [(0.7 x spring cover) + (0.3 x spring food)]

HSR (Summer/Fall) = [(0.5 x summer/fall cover) + (0.5 x summer/fall food)]

Habitat Suitability Index (HSI)

HSI (Spring) = HSR (Spring)/3

HSI (Summer/Fall) = HSR (Summer/Fall)/3

HSI (Overall) = [0.7 (HSI Spring) + 0.3 (HSI Summer/Fall)]

Table: 9-31 Willow Creek Wildlife Capability Model - Mallard

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Spring	0.7	Cover	0.6	Cover type	0	-bare soil/rock
					3	-seasonal wetland
					3	-permanent wetland/ open water
					1	-native grassland
					1	-improved pasture
					2	-cropland
					2	-shrub meadow (10-50% shrub cover)
					1	-shrubland (>50% shrub cover)
					1	-conifer parkland (10-50% tree cover)
					1	-deciduous parkland
					0	-conifer forest (>50% tree cover)
					0	-deciduous forest (>50% tree cover)
					0	-mixed forest (>50% tree cover)
			N/A	Slope characteristics		-steep, broken (>30° slopes predominate)
						-moderate, rolling (10-30°)
						-flat (<10°)
			N/A	Major aspects		-cool slopes (W-N-SE)
						-warm slopes (SE-S-W)
						-flat
			0.3	Stream permanency	2	-intermittent
					3	-permanent
			0.1	Stream sinuosity	1	-straight
					2	-curved
					3	-meandering

Table: 9-31 (cont'd) Willow Creek Wildlife Capability Model - Mallard

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Spring	0.3	Food	0.6	Cover type	0	-bare soil/rock
					3	-seasonal wetland
					3	-permanent wetland/ open water
					1	-native grassland
					1	-improved pasture
					2	-cropland
					1	-shrub meadow (10-50% shrub cover)
					0	-shrubland (>50% shrub cover)
					0	-conifer parkland (10-50% tree cover)
					0	-deciduous parkland
					0	-conifer forest (>50% tree cover)
					0	-deciduous forest (>50% tree cover)
					0	-mixed forest (>50% tree cover)
			N/A	Slope characteristics		-steep, broken (>30° slopes predominate)
						-moderate, rolling (10-30°)
						-flat (<10°)
			N/A	Major aspects		-cool slopes (W-N-SE)
						-warm slopes (SE-S-W)
						-flat
			0.3	Stream permanency	2	-intermittent
					3	-permanent
			0.1	Stream sinuosity	1	-straight
					2	-curved
					3	-meandering

Table: 9-31 (cont'd) Willow Creek Wildlife Capability Model - Mallard

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Summer/ Fall	0.5	Cover	0.4	Cover type	0	-bare soil/rock
					1	-seasonal wetland
					3	-permanent wetland/ open water
					0	-native grassland
					0	-improved pasture
					0	-cropland
					0	-shrub meadow (10-50% shrub cover)
					0	-shrubland (>50% shrub cover)
					0	-conifer parkland (10-50% tree cover)
					0	-deciduous parkland
					0	-conifer forest (>50% tree cover)
					0	-deciduous forest (>50% tree cover)
					0	-mixed forest (>50% tree cover)
			N/A	Slope characteristics		-steep, broken (>30° slopes predominate)
						-moderate, rolling (10-30°)
						-flat (<10°)
			N/A	Major aspects		-cool slopes (W-N-SE)
						-warm slopes (SE-S-W)
						-flat
			0.4	Stream permanency	1	-intermittent
					3	-permanent
			0.2	Stream sinuosity	1	-straight
					2	-curved
					3	-meandering

Table: 9-31 (concluded) Willow Creek Wildlife Capability Model - Mallard

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Summer/ Fall	0.5	Food	0.6	Cover type	0	-bare soil/rock
					1	-seasonal wetland
					3	-permanent wetland/ open water
					1	-native grassland
					1	-improved pasture
					3	-cropland
					1	-shrub meadow (10-50% shrub cover)
					0	-shrubland (>50% shrub cover)
					0	-conifer parkland (10-50% tree cover)
					0	-deciduous parkland
					0	-conifer forest (>50% tree cover)
					0	-deciduous forest (>50% tree cover)
					0	-mixed forest (>50% tree cover)
			N/A	Slope characteristics		-steep, broken (>30° slopes predominate)
						-moderate, rolling (10-30°)
						-flat (<10°)
			N/A	Major aspects		-cool slopes (W-N-SE)
						-warm slopes (SE-S-W)
						-flat
			0.2	Stream permanency	1	-intermittent
					3	-permanent
			0.2	Stream sinuosity	1	-straight
					2	-curved
					3	-meandering

Table 9-32. Habitat availability summary -Willow Creek Mallard

REACH NUMBER	AREA (HA)	HSI-SPRING COVER	HSI-SPRING FOOD	HSI-SPRING TOTAL	SPRING-HAB UNITS	HSI-FALL COVER	HSI-FALL FOOD	HSI-FALL TOTAL	FALL-HAB UNITS
1	19.6	0.39	0.17	0.55	10.86	0.30	0.23	0.53	10.35
2	57.9	0.40	0.17	0.58	33.33	0.30	0.23	0.53	30.86
3	34.6	0.55	0.17	0.72	25.04	0.30	0.28	0.58	19.93
4	45	0.45	0.16	0.61	27.49	0.30	0.26	0.56	25.11
5	23.2	0.38	0.15	0.52	12.09	0.30	0.22	0.52	12.02
6	31.2	0.43	0.18	0.61	18.97	0.30	0.25	0.55	17.28
7	46.5	0.44	0.17	0.61	28.34	0.30	0.27	0.57	26.37
8	32.1	0.45	0.17	0.62	19.83	0.30	0.26	0.56	18.07
9	43	0.46	0.17	0.63	27.24	0.30	0.26	0.56	24.08

TOTAL AREA = 333.1

TOTAL SPRING HABITAT UNITS = 203.84

TOTAL FALL HABITAT UNITS = 184.66

SPRING HABITAT UNITS PER HA = 0.61

FALL HABITAT UNITS PER HA = 0.55

Table 9-33. Habitat availability summary- Pine Coulee (Site 2) Mallard

REACH NUMBER	AREA (HA)	HSI FALL COVER	HSI FALL FOOD	HSI FALL TOTAL	FALL HAB UNITS	HSI SPRING COVER	HSI SPRING FOOD	HSI SPRING TOTAL	SPRING HAB UNITS
1	17.5	0.17	0.23	0.40	7.00	0.47	0.15	0.62	10.78
2	17.6	0.17	0.23	0.40	7.04	0.35	0.15	0.50	8.80
3	20.2	0.10	0.17	0.27	5.39	0.32	0.13	0.45	9.01
4	12.4	0.13	0.20	0.33	4.13	0.44	0.14	0.58	7.16
5	18.8	0.10	0.16	0.26	4.98	0.42	0.13	0.55	10.28
6	22.6	0.10	0.16	0.26	5.85	0.42	0.13	0.54	12.22
7	22.5	0.13	0.19	0.32	7.30	0.41	0.13	0.55	12.27
8	24.4	0.17	0.20	0.36	8.83	0.35	0.13	0.48	11.64
9	13.7	0.13	0.20	0.33	4.57	0.33	0.14	0.47	6.39
10	10.2	0.13	0.20	0.33	3.40	0.43	0.14	0.57	5.83
11	8.7	0.10	0.17	0.27	2.32	0.44	0.13	0.57	4.99
12	17.1	0.17	0.23	0.40	6.84	0.49	0.15	0.64	10.94
13	33.4	0.13	0.20	0.33	11.17	0.36	0.14	0.50	16.82
14	34	0.17	0.23	0.39	13.40	0.34	0.15	0.49	16.59
15	15.1	0.10	0.14	0.24	3.68	0.27	0.12	0.39	5.85

TOTAL AREA= 288.2

TOTAL FALL HABITAT UNITS = 95.88

TOTAL SPRING HABITAT UNITS = 149.58

FALL HABITAT UNITS PER HA = 0.33

SPRING HABITAT UNITS PER HA= 0.52

Table 9-34. Habitat availability summary- Pine Coulee (Site 4) Mallard

REACH NUMBER	AREA (HA)	HSI FALL COVER	HSI FALL FOOD	HSI FALL TOTAL	FALL HAB UNITS	HSI SPRING COVER	HSI SPRING FOOD	HSI SPRING TOTAL	SPRING HAB UNITS
1	17.5	0.17	0.23	0.40	7.00	0.47	0.15	0.62	10.78
2	17.6	0.17	0.23	0.40	7.04	0.35	0.15	0.50	8.80
3	20.2	0.10	0.17	0.27	5.39	0.32	0.13	0.45	9.01
4	12.4	0.13	0.20	0.33	4.13	0.44	0.14	0.58	7.16
5	18.8	0.10	0.16	0.26	4.98	0.42	0.13	0.55	10.28
6	22.6	0.10	0.16	0.26	5.85	0.42	0.13	0.54	12.22
7	22.5	0.13	0.19	0.32	7.30	0.41	0.13	0.55	12.27
8	24.4	0.17	0.20	0.36	8.83	0.35	0.13	0.48	11.64
9	13.7	0.13	0.20	0.33	4.57	0.33	0.14	0.47	6.39
10	10.2	0.13	0.20	0.33	3.40	0.43	0.14	0.57	5.83
11	8.7	0.10	0.17	0.27	2.32	0.44	0.13	0.57	4.99
12	17.1	0.17	0.23	0.40	6.84	0.49	0.15	0.64	10.94
13	33.4	0.13	0.20	0.33	11.17	0.36	0.14	0.50	16.82
14	34	0.17	0.23	0.39	13.40	0.34	0.15	0.49	16.59
15	15.1	0.10	0.14	0.24	3.58	0.27	0.12	0.39	5.85
16	42.9	0.17	0.21	0.38	16.22	0.32	0.14	0.46	19.74
17	19.3	0.13	0.18	0.32	6.11	0.31	0.13	0.44	8.46
18	20.8	0.17	0.19	0.35	7.32	0.41	0.12	0.53	10.97
19	38.8	0.17	0.17	0.34	13.11	0.37	0.11	0.49	18.88
20	27.8	0.13	0.21	0.34	9.52	0.37	0.15	0.52	14.33
21	69.1	0.13	0.15	0.28	19.58	0.30	0.11	0.41	28.14

TOTAL AREA= 506.9

TOTAL FALL HABITAT UNITS = 167.73

TOTAL SPRING HABITAT UNITS = 250.10

FALL HABITAT UNITS PER HA = 0.33

SPRING HABITAT UNITS PER HA = 0.49

Table 9-35. Habitat availability summary- Kuntz Creek Mallard

REACH NUMBER	TOTAL AREA	HSI-SPRING COVER	HSI-SPRING FOOD	HSI-SPRING TOTAL	SPRING-HAB UNITS	HSI-FALL COVER	HSI-FALL FOOD	HSI-FALL TOTAL	FALL-HAB UNITS
1	8.1	0.40	0.11	0.51	4.10	0.27	0.17	0.43	3.51
2	8.3	0.40	0.11	0.51	4.21	0.27	0.17	0.43	3.60
3	12.6	0.40	0.12	0.52	6.50	0.30	0.20	0.50	6.30
4	72	0.52	0.22	0.75	53.68	0.30	0.46	0.76	54.36
5	38.7	0.44	0.19	0.63	24.30	0.30	0.34	0.64	24.69
6	17.8	0.41	0.14	0.55	9.73	0.30	0.24	0.54	9.52
7	12	0.33	0.11	0.44	5.31	0.27	0.17	0.43	5.20
8	9.4	0.31	0.12	0.42	3.97	0.27	0.18	0.45	4.24
9	11	0.33	0.12	0.45	4.97	0.27	0.18	0.45	4.92
10	6.4	0.29	0.11	0.40	2.59	0.27	0.17	0.43	2.77
11	8.6	0.26	0.11	0.37	3.15	0.27	0.17	0.43	3.73

TOTAL AREA = 204.9

TOTAL SPRING HABITAT UNITS = 122.52

FALL HABITAT UNITS = 122.84

SPRING HABITAT UNITS PER HA = 0.60

FALL HABITAT UNITS PER HA = 0.60

9.8 GREAT BLUE HERON HABITAT SUITABILITY MODEL

9.8.1 Existing Models/Data bases

Available information on the status and general ecology of great blue herons in Alberta has been summarized by Brechtel (1981). Green et al. (1984) also provide a review of the habitat requirements of this species, with particular reference to Alberta wetlands.

9.8.2 Major Habitat Requirements

Great blue herons nest in colonies along the shores of lakes and rivers, normally choosing the tops of the tallest available trees for nest sites. In Alberta, poplars are the most commonly used nesting trees. Nests are reused year after year, and some colonies are known to have used the same location for several decades. However, colonies may be abandoned or relocated in response to prolonged disturbance or as a result of the death of the nesting trees; also, recent studies in British Columbia have shown that colonies are more dynamic than previously thought, changing location from year to year, splitting into subgroups, and possibly even interchanging birds. Subsequent to fledging, great blue herons disperse from the colony sites.

This species feeds in a variety of shallow water situations, mainly on aquatic vertebrates and large invertebrates.

9.8.3 Model Development (see Table 9-36)

Because great blue herons feed primarily on animal material, often far from colony sites, it was not considered feasible to quantify food availability using the biophysical variables selected for this study. The model focuses instead on an evaluation of potential nesting habitat. As in the beaver model, evaluation of habitat capability is based on stream reaches each 1 km in length, extending the full width of the floodplain.

Deciduous trees adjacent to permanent water provide optimum nesting conditions for this species, and cover type and stream permanency are therefore the major variables in the model. Stream sinuosity has been included as it provides a measure of the actual length of streamside habitat within a stream reach. The availability of deciduous trees is considered to be a critical factor; in stream reaches that do not support deciduous forest, deciduous parkland or mixed forest the model value goes to zero, regardless of the values contributed by the stream permanency and sinuosity variables.

9.8.4 Calculation of Habitat Suitability

The following formulae were used to determine the suitability of each 1 km by 200 m stream reach as great blue heron nesting habitat:

HSR = [0.5 x (cover type x proportion of cover type in land system)] + [0.3 x stream permanency] + [0.2 x stream sinuosity] x 0 if cover type value is 0.

HSI = HSR/3

Table: 9-36 Willow Creek Wildlife Capability Model - Great Blue Heron

SEASON	WT	LIFE REQUISITE	WT	VARIABLE	RATING	CATEGORY
Nesting	1.0	Nest (Colony Sites)	0.5	Cover type	0	-bare soil/rock
					0	-seasonal wetland
					0	-permanent wetland/ open water
					0	-native grassland
					0	-improved pasture
					0	-cropland
					0	-shrub meadow (10-50% shrub cover)
					0	-shrubland (>50% shrub cover)
					0	-conifer parkland (10-50% tree cover)
					2	-deciduous parkland
					0	-conifer forest (>50% tree cover)
					3	-deciduous forest (>50% tree cover)
					1	-mixed forest (>50% tree cover)
			N/A	Slope characteristics		-steep, broken (>30° slopes predominate)
						-moderate, rolling (10-30°)
						-flat (<10°)
			N/A	Major aspects		-cool slopes (W-N-SE)
						-warm slopes (SE-S-W)
						-flat
			0.3	Stream permanency	1	-intermittent
					3	-permanent
			0.2	Stream sinuosity	1	-straight
					2	-curved
					3	-meandering

Table 9-37. Habitat availability summary- Willow Creek Great Blue Heron

REACH NUMBER	AREA (HA)	HSI NESTING	HABITAT UNITS
1	19.6	0.74	14.41
2	57.9	0.76	43.71
3	34.6	0.58	20.07
4	45	0.57	25.65
5	23.2	0.63	14.50
6	31.2	0.73	22.78
7	46.5	0.66	30.46
8	32.1	0.57	18.14
9	43	0.66	28.17

TOTAL AREA = 333.1

TOTAL UNITS = 217.87

UNITS PER HA = 0.65

Table 9-38. Habitat availability summary- Pine Coulee (Site 2) Great Blue Heron

REACH NUMBER	AREA (HA)	HSI NESTING	HABITAT UNITS
1	17.5	0.00	0.00
2	17.6	0.00	0.00
3	20.2	0.00	0.00
4	12.4	0.00	0.00
5	18.8	0.00	0.00
6	22.6	0.00	0.00
7	22.5	0.00	0.00
8	24.4	0.00	0.00
9	13.7	0.00	0.00
10	10.2	0.00	0.00
11	8.7	0.00	0.00
12	17.1	0.00	0.00
13	33.4	0.00	0.00
14	34	0.00	0.00
15	15.1	0.00	0.00

TOTAL AREA = 288.2

TOTAL HABITAT UNITS = 0.00

HABITAT UNITS PER HA = 0.00

Table 9-39. Habitat availability summary- Pine Coulee (Site 4) Great Blue Heron

REACH NUMBER	AREA (HA)	HSI NESTING	HABITAT UNITS
1	17.5	0.00	0.00
2	17.6	0.00	0.00
3	20.2	0.00	0.00
4	12.4	0.00	0.00
5	18.8	0.00	0.00
6	22.6	0.00	0.00
7	22.5	0.00	0.00
8	24.4	0.00	0.00
9	13.7	0.00	0.00
10	10.2	0.00	0.00
11	8.7	0.00	0.00
12	17.1	0.00	0.00
13	33.4	0.00	0.00
14	34	0.00	0.00
15	15.1	0.00	0.00
16	42.9	0.21	8.83
17	19.3	0.17	3.35
18	20.8	0.24	4.91
19	38.8	0.21	8.34
20	27.8	0.18	5.00
21	69.1	0.19	13.06

TOTAL AREA= 506.9

TOTAL HABITAT UNITS = 43.48

HABITAT UNITS PER HA = 0.09

Table 9-40. Habitat availability summary- Kuntz Creek Great Blue Heron

REACH NUMBER	AREA (HA)	HSI NESTING	HABITAT UNITS
1	8.1	0.00	0.00
2	8.3	0.00	0.00
3	12.6	0.59	7.37
4	72	0.56	40.32
5	38.7	0.55	21.29
6	17.8	0.56	9.97
7	12	0.58	6.94
8	9.4	0.59	5.58
9	11	0.84	9.22
10	6.4	0.00	0.00
11	8.6	0.93	8.03

TOTAL AREA = 204.9

TOTAL HABITAT UNITS = 108.71

HABITAT UNITS PER HA = 0.53

10.0 APPENDIX II

Biophysical Mapping Legend and Definitions

Agriculture Canada, 1977. The Canadian System of Soil Classificiation. Department of Supply and Services, Ottawa.

Embleton, C. and C.A.M. King, 1968. Glacial and Periglacial Geomorphology. Edward Arnold Ltd., London.

Flint, R.F. and B.J. Skinner. 1977. Physical Geology (2nd Ed.). John Wiley and Sons, New York.

Strahler, A.N. and A.H. Strahler. 1978. Modern Physical Geography. John Wiley and Sons, New York.

10.1 LAND SYSTEM

10.1.1 GEOMORPHOLOGY

B	Bedrock	- Consolidated rock; in this study includes unweathered sedimentary rock.
C	Colluvial	- Massive to moderately well stratified, non-sorted to poorly sorted sediments with any range of particle sizes from clay to boulders and blocks that have reached their present position by direct, gravity induced movement.
F	Fluvial	- Sediment generally consisting of gravel and sand with a minor fraction of silt and rarely clay. The gravels are typically rounded and contain interstitial sand. Fluvial sediments are commonly moderately to well-sorted and display stratification, although massive, non-sorted fluvial gravels do occur. These materials have been transported and deposited by streams and rivers.
G	Glacio-Fluvial	- Sediment accumulation formed by meltwater stream issuing from a glacier terminus; commonly composed of stratified materials.
M	Morainal	- Sediment generally consisting of well-compacted material that is non-stratified and contains a heterogeneous mixture of particle sizes, often in a mixture of sand, silt and clay that have been transported beneath, beside, on, within and in front of a glacier and not modified by any intermediate agent.
O	Other	- As per Table 10-1.

Table10-1 Biophysical mapping legend for potential reservoir sites in Willow Creek study area.

1. LAND SYSTEM (RED LINES)

1.1 Geomorphology

B	Bedrock
C	Colluvium
F	Fluvial
G	Glacio-Fluvial
M	Moraine
O	Other (Residual, Anthropogenic undifferentiated)

1.2 Landform

o	outcrop
f	fan
c	channel
t	terrace
w	mass wastage or sheet wash
m	meltwater channel
l	active floodplain, oxbows, meander scars
g	ground moraine
z	other (anthropogenic, etc.)

1.3 Slope

1.	0-10°
2.	10-30°
3.	>30°

1.4 Surface Expression

g	gullied
e	eroded
h	hummocky
i	inclined
l	level to undulating
m	rolling
r	ridged
t	terraced
v	veneer

1.5 Aspect

F	Flat or Variable
N	North (NW-N-SE)
S	South (SE-S-NW)

2. LAND TYPE (BLACK LINES)

2.1 Ground Cover

B	Bare Soil/Rock
C	Coniferous Trees (>50% treed)
D	Deciduous Trees (>50% treed)
H	Shrub Meadow (10-50% shrubs)
I	Shrubland (>50% shrubs)
K	Coniferous Parkland (10-50% treed)
L	Deciduous Parkland (10-50% treed)
M	Mixed Forest (>50% treed)
N	Native Grassland
P	Seeded Pasture
R	Cultivated Crop
S	Seasonal Wetland
W	Permanent Wetland
O	Open Water

2.2 Soil

c	Chernozem
g	Gleysol
l	Luvisol
o	Rock, Gravel
r	Regosol
s	Rego Gleysol, saline phase

2.3 Drainage

1.	Poor
2.	Imperfect
3.	Moderate
4.	Well to Rapid

10.2 LAND FORMS

o	Outcrop	- The area on a geological map, shown as occupied by a particular rock unit. - Surface exposure of bedrock.
f	Fan	- A fan-shaped body of alluvium built at the base of a steep slope. - (alluvial) gently sloping, conical accumulation of coarse alluvium deposited by a braided stream undergoing aggradation below the point of emergence of the channel from a narrow canyon or gully.
c	Channel	- Long, narrow, troughlike depression occupied and shaped by a stream moving progressively lower levels.
t	Terrace	- A bench along the side of a valley, the upper surface of which was formerly the alluvial floor of the valley.
w	Mass Wasting	- The movement of regolith downslope by gravity without the aid of a stream, a glacier or wind. - Spontaneous downward movement of soil and/or rock under the influence of gravity does not include the action of fluid agents.
	Sheet Wash	- The erosion performed by overland flow. - Phase of accelerated soil erosion in which thin layers of soil are removed without formation of shoestring rills or gullies.
m	Meltwater Channel	- An erosional form created directly from high volumes of meltwater flowing from wasting ice.
l	Active Floodplain	- That part of any stream valley which is inundated during floods. - Belt of low, flat ground present on one or both sides of a stream channel, subject to inundation by a flood about once annually and underlain by alluvium.
	Oxbow	- Crescent-shaped lake or swamp representing the abandoned channel left by the cutoff of an alluvial meander.

Meander Scar - A looplike bend of stream channel.

g Ground Moraine - Widespread thin drift with a smooth surface consisting of gently sloping knolls and shallow closed depressions.

- Moraine distributed beneath a large expanse of land surface covered at one time by an ice sheet.

z Other - Landform represents anthropogenic disturbance or a type not included under any other category.

10.3 SLOPE - as per Table 10-1.

10.4 SURFACE EXPRESSION

g Gullied - The modification of surface by fluvial erosion resulting in the development of parallel and subparallel, steep-sided, and narrow ravines in both consolidated and unconsolidated materials.

e Eroded - Surface modified by the sorting out, lifting and removal of loose, dry, fine-gravelled particles (clay and silt sizes) by the turbulent eddy action of the wind by the formation of tension fractures or by large consolidated or unconsolidated masses moving slowly downslope resulting in exposed bedrock or bare soil.

h Hummocky - A very complex sequence of slopes extending from somewhat rounded depressions or kettles of various sizes to irregular to conical knolls or knobs. There is a general lack of concordance between knolls or depressions. Slopes are generally 9-70% (5-35°).

i Inclined - A sloping, unidirectional surface with a generally constant slope not broken by marked irregularities. Slopes are 2-70% (1-35°). The form of inclined slopes is not related to the initial mode or origin of the underlying material.

l Level - A flat or very gently sloping, unidirectional surface with a generally constant slope not broken by marked elevations and depressions. Slopes are generally less than 2% (1°).

Undulating - A very regular sequence of gentle slopes that extends from rounded, sometimes confined concavities to broad rounded convexities producing a wavelike pattern of low local relief. Slope length is generally less than 0.8 km and the dominant gradient of slope is 2-5% (1-3°).

m Rolling - A very regular sequence of moderate slopes extending from rounded, sometimes confined concave depressions to broad, rounded convexities producing a wavelike pattern of moderate relief. Slope length is often great and gradients are greater than 5% (3°).

r Ridged - A long, narrow elevation of the surface, usually sharp crested with steep sides. The ridges may be parallel, subparallel, or intersecting.

t Terraced - Scarp face and the horizontal or gently inclined surface (tread) above it.

v	Veneer	- Unconsolidated materials too thin to mask the minor irregularities of the underlying unit surface. A veneer will range from 10 cm to 1 m in thickness and will possess no form typical of the material's genesis.

10.5 ASPECT - as per Table 10-1.

10.6 SOIL

c Chernozemic Order

The general concept of the Chernozemic order is that of well to imperfectly drained soils having surface horizons darkened by the accumulation of organic matter from the decomposition of xerophytic or mesophytic grasses and forbs representative of grassland communities or grassland-forest communities with associated shrubs and forbs. The major area of Chernozemic soils occur in some valleys and mountain slopes in the Cordilleran Region extending in some cases beyond the tree line. Most Chernozemic soils are frozen during some period each winter and their sola are dry at some period each summer. Their mean annual temperature is higher than 0°C and usually less than 5.5°C.

g Gleysolic Order

Soils of the Gleysolic order have features indicative of periodic or prolonged saturation with water and reducing conditions. They occur commonly in association with other soils in the landscape. In areas of subhumid climate, Gleysolic soils occur commonly in shallow depressions and on level lowlands that are saturated with water every spring. In more humid areas, they occur also on slopes and on undulating terrain. Gleysolic soils are usually associated with either a high groundwater table at some period of the year or temporary saturation above a relatively impermeable layer. Some Gleysolic soils may be submerged under shallow water throughout the year. Commonly the native vegetation associated with Gleysolic soils differs from that of nearby soils of other orders.

l Luvisolic Order

Soils of the Luvisolic order generally have light-colored, eluvial horizons and they have illuvial B horizons in which silicate clay has accumulated. These soils develop characteristically in well to imperfectly-drained sites, in sandy loam to clay base-saturated parent materials under forest vegetation in subhumid to humid, mild to very cold climates. Depending on the combination of soil environmental factors, some Luvisolic soils occur under conditions outside the range indicated as characteristic.

r Regosolic Order

Regosolic soils are very weakly developed. The lack of development of genetic horizons may be due to any of a number of factors: youthfulness of the material, recent alluvium; instability of the material, colluvium on slopes subject to mass wasting; nature of the material, nearly pure quartz sand; climate, dry cold conditions. Regosolic soils are generally rapidly to imperfectly drained. They occur under a wide range of vegetation and climates.

s Rego Gleysol, saline phase

Common horizon sequence: LFH or O, Cg

These soils have the general properties specified for the Gleysolic order and the Gleysol great group. They differ from the Orthic Gleysols by lacking a B horizon at least 5 cm thick. Thus they consist of a gleyed C horizon with or without organic surface horizons and a thin Ah or B horizon. The saline phase has an accumulation of soluble salts in the surface horizon(s), that produces an electrical conductivity of greater than 4 mS/cm.

11.0 APPENDIX III

Known Prehistoric and Historic Sites Potentially Impacted by Reservoir Development Within the Willow Creek Basin

SITE NO. 1, WILLOW CREEK NEAR CLARESHOLM

BORDEN NO: EaPk 4 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL069506 LEGAL REF: NE.NW.12.13.28.4

SITE TYPE: Bison kill

LOCATION: 4.5 miles west of Pulteney, 0.2 miles south in the valley of Willow Creek (east side).

DESCRIPTION: Scattered bison bones in the bottom of a small dry wash about 3 ft. deep. Bones covered an area of about 10 ft. diameter. None exposed in cutbank of wash. A bit of gravel may indicate alluvial redeposition.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 5 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL067505 LEGAL REF: SW.SW.13.13.28.4

SITE TYPE: Buried Campsite

LOCATION: 4.2 miles west of Pulteney, 0.2 miles south in the valley of Willow Creek (east side).

DESCRIPTION: In a cutbank of the lowest terrace of the river. Scattered bone and artifactual material, two probable hearths but no firebroken rock observed 6 in. below ground surface.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 6 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL066505 LEGAL REF: NW.NW.12.13.28.4

SITE TYPE: Bison Kill

LOCATION: 4.3 miles west and 0.2 miles south of Pulteney in the valley of Willow Creek (east side).

DESCRIPTION: Articulated butchered bison vertebrae exposed at 2 ft. below surface at northwest end of a long cutbank of Willow Creek.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO:	EaPk 7	MAP REF:	82I/4 Claresholm
U.T.M.:	12UUL068517-8	LEGAL REF:	NE.NW.13.13.28.4

SITE TYPE: Hearth

LOCATION: 4.2 miles west of Pulteney, 0.75 miles north in the valley wall of Willow Creek.

DESCRIPTION: Site consists of a rock pattern, possibly a turtle effigy, and a hearth, buried 16 in. below the surface in a cutbank of a small draw perpendicular to the valley wall. In a buried soil over clay horizon. Two rocks visible above hearth and contiguous to it. Fragments of bone were observed.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO:	EaPk 8	MAP REF:	82I/4 Claresholm
U.T.M.:	12UUL075498	LEGAL REF:	SE.NE.12.13.28.4

SITE TYPE: Blowout (Isolated Finds)

LOCATION: 4.2 miles west of Pulteney, 0.5 miles south in the valley of Willow Creek.

DESCRIPTION: A cobble chopper and a lead-cased bullet were found 2 feet apart in a blowout south of the road going from Best's house down into the valley.

CULTURAL AFFILIATIONS: Unknown Prehistoric/Historic

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO:	EaPk 9	MAP REF:	82I/4 Claresholm
U.T.M.:	12UUL074504	LEGAL REF:	NW.NE.12.13.28.4

SITE TYPE: Surface Scatter

LOCATION: 4.2 miles west of Pulteney, on prairie level overlooking the Willow Creek valley.

DESCRIPTION: Firebroken rock, bone fragments, and artifactual material were observed scattered over the ploughed field.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 10 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL069503 LEGAL REF: ?.NW.12.13.28.4

SITE TYPE: Hearth

LOCATION: 4.3 miles west and 0.2 miles south of Pulteney in the valley of Willow Creek.

DESCRIPTION: One hearth, 2 ft. across, visible only as a dark blemish in the soil matrix, with a few small lumps of charcoal. Situated in a slanting cut in the middle of a cat/tractor trail cut through the bushes.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 11 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL073490-2 LEGAL REF: SW.SE.12.13.28.4

SITE TYPE: Kill/Burials

LOCATION: 4.2 miles west of Pulteney, 0.75 miles south on promontory overlooking Willow Creek valley.

DESCRIPTION: A river cut, 10-12 ft. high, showing broken (possibly butchered) bone 15 in. below surface. Concentrations of bone not very good. Possible burials in bedrock cliffs forming promontory on crest of hill - in crevices. One crevice in particular seemed to have considerable depth inside - deposit 18 inches to 2 feet thick.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 24 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL046536 LEGAL REF: NE.NE.22.13.28.4

SITE TYPE: Bison Jump

LOCATION: 6 miles west and 5 miles north of Claresholm in a small coulee on Willow Creek.

DESCRIPTION: Three bison skulls and scattered bone were observed in a 10 ft. high cutbank on the east side of Willow Creek in 6 or more levels.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 31 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: NE.SE.23.13.28.4

SITE TYPE: Bison Jump

LOCATION: 6 miles west and 5 miles north of Claresholm on east side of Willow Creek.

DESCRIPTION: Site is 200 yds. from east side of Willow Creek at a 20 ft. high cliff. Near EaPk 71.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 34 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL072485 LEGAL REF: W½.NE.1.13.28.4

SITE TYPE: Surface (Campsite)

LOCATION: 1 mile north and 1 mile west of Claresholm on prairie level overlooking Willow Creek.

DESCRIPTION: Firebroken rock, flakes, pottery, and a side scraper were found in a ploughed field.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 35 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL062474 LEGAL REF: SE.SE.2.13.28.4

SITE TYPE: Bison Jump (?)

LOCATION: 5 miles west and 1 mile north of Claresholm about 200 yds. west of Willow Creek in old river cut.

DESCRIPTION: Scattered bone was observed in some auger holes.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 36 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL049532 LEGAL REF: SE.NW.23.13.28.4

SITE TYPE: Cairns

LOCATION: 6 miles west and 5.0 miles north of Claresholm. Cairns are on flats between two draws with farmers rock piles in them.

DESCRIPTION: On prairie level, 300 yds. from east side of Willow Creek, 10 yds. from edge, 1 cairn 3 ft. in diameter and 2 cairns 2.5 ft. in diameter were located. Lichen covering the rocks was slight and deposition around them was medium. 1 cairn (3 ft.) located near the fence, the others were near the bluff leading to the river flats.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1969

BORDEN NO: EaPk 38 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: SE.NE.23.13.28.4

SITE TYPE: Pictographs

LOCATION: 7.5 miles west and 2.5 miles south of Stavely at the sandstone outcroppings on the west side of Willow Creek.

DESCRIPTION: An animal shape in brownish-red paint is discernible. The pinkish smudges which appear in several places may be the remains of pictographs, eg. a badly eroded hand is discernible.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO:	EaPk 50	MAP REF:	82I/4 Claresholm
U.T.M.:	12UUL064481	LEGAL REF:	NW.SW.1.13.28.4

SITE TYPE: Tipi Rings

LOCATION: West of Stavely on a bluff overlooking Willow Creek from the west.

DESCRIPTION: Five rings, about 15 ft. in diameter. Deeply buried. Associated are three possible cairns about 3 ft. across with small rocks.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO:	EaPk 64	MAP REF:	82I/4 Claresholm
U.T.M.:	12UUL063522	LEGAL REF:	NE.NE.14.13.28.4

SITE TYPE: Cairns

LOCATION: 4.5 miles west and 0.75 miles north of Pulteney. Both cairns are ca. 50 yds. north of the metal granary.

DESCRIPTION: Two cairns on prairie level, 200 yds. from farmhouse. Apparently single tier. Diameter of piles from 6 in. to 1 ft. Lichen cover is medium and deposition around rocks is medium.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1969

BORDEN NO:	EaPk 65	MAP REF:	82I/4 Claresholm
U.T.M.:	12UUL059522	LEGAL REF:	NW.NE.14.13.28.4

SITE TYPE: Buried Campsite

LOCATION: 4.5 miles west and 1 mile north of Pulteney on a high terrace above Willow Creek.

DESCRIPTION: Firebroken rock observed in a washout on the slope of a hill and a few feet east a possible hearth. Scattered refuse is heavy but very few firebroken rocks were scattered in the cattle trail.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1969

BORDEN NO: EaPk 66 MAP REF: 82I/4 Claresholm
U.T.M.: 12UUL059520 LEGAL REF: NE.NE.14.13.28.4

SITE TYPE: Buried Campsite

LOCATION: 5 miles west and 1 mile north of Pulteney on prairie level overlooking farmhouse to the west.

DESCRIPTION: A few flakes and worked petrified wood was observed along a cattle trail. Firebroken rock was also observed.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1969

BORDEN NO: EaPk 67 MAP REF: 82I/4 Claresholm
U.T.M.: 12UUL060524 LEGAL REF: SE.SE.23.13.28.4

SITE TYPE: Surface Campsite

LOCATION: 4.5 miles west and 2 miles north of Pulteney on the east side of Willow Creek.

DESCRIPTION: Scattered refuse was observed in an old ploughed field; the rocks are small and clustered in confined areas. A few pieces of firebroken rock, flakes, and scrapers were observed in recently ploughed field.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1969

BORDEN NO: EaPk 68 MAP REF: 82I/4 Claresholm
U.T.M.: 12UUL056525 LEGAL REF: SW.SE.23.13.28.4

SITE TYPE: Surface Campsite

LOCATION: 4.4 miles west and 2 miles north of Pulteney on east side of Willow Creek.

DESCRIPTION: A diffuse scatter of flakes were observed 200 yds. east of Willow Creek. Two flakes and 6 possible cobble choppers were collected.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1969

BORDEN NO: EaPk 69 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL054528 LEGAL REF: NE.SW.23.13.28.4

SITE TYPE: Cairn

LOCATION: 6 miles west and 5 miles north of Claresholm on prairie level and at south end of gravel pit on east side of Willow Creek.

DESCRIPTION: A scattered cairn, 8 ft. N-S by 2.5 ft. E-W was found. Cairn is roughly rectangular and is 100 yds. from river bluffs immediatedly to the south.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1969

BORDEN NO: EaPk 70 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL053526 LEGAL REF: SE.SW.23.13.28.4

SITE TYPE: Buried Campsite

LOCATION: 6 miles west and 5 miles north of Claresholm on a high terrace of Willow Creek approximately 200 yds. southwest of an existing gravel pit.

DESCRIPTION: Scattered flakes were observed exposed in a cut bank of Willow Creek. Cultural material was observed approximately 1 ft. above till. Bone and firebroken rock also observed.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1969

BORDEN NO: EaPk 71 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL051-2 529-30 LEGAL REF: NE.SW.23.13.28.4

SITE TYPE: Cairn/Campsite

LOCATION: 6 miles west and 5 miles north of Claresholm, 100 yds. south of farmhouse along old trail to south side of valley floor, on east side of Willow Creek.

DESCRIPTION: Cairn, approximately 6 ft. in diameter, was found 300 yds. from east side of Willow Creek, 20 yds. from fence, in the trail cut. Lichen cover is medium as is deposition around rocks. Firebroken rock observed. Scattered refuse in same areas as cairn.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 72 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL051527 LEGAL REF: NE.SW.23.13.28.4

SITE TYPE: Burial

LOCATION: 6 miles west and 4.5 miles north of Claresholm at sandstone bluffs on the east side of Willow Creek.

DESCRIPTION: Square nails and glass beads were found on the surface at the north end of a crevice of a 2 ft. high overhang. The burial (secondary) was excavated in 1968. Flakes, dentalia shell and trade goods were recovered.

CULTURAL AFFILIATIONS: Protohistoric

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 73 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL050529 LEGAL REF: NW.SW.23.13.28.4

SITE TYPE: Rock Shelter (Campsite)

LOCATION: West of Claresholm, at cliffs 200 yds. east of Willow Creek.

DESCRIPTION: Butchered bone observed and recovered at a depth of approximately 1 ft. from shovel holes excavated below an overhanging sandstone cliff approximately 30 ft. high and 150 ft. long.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 74 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL049532 LEGAL REF: SW.NW.23.13.28.4

SITE TYPE: Surface Campsite

LOCATION: 6 miles west and 5 miles north of Claresholm on first terrace on east side of Willow Creek.

DESCRIPTION: A scattered refuse (flakes) was observed in a ploughed field 10 ft. from discontinued road.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1969

BORDEN NO: EaPk 75 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL048534 LEGAL REF: SW.NW.23.13.28.4

SITE TYPE: Surface Campsite

LOCATION: 6 miles west and 5 miles north of Claresholm on east side of Willow Creek.

DESCRIPTION: A scatter of flakes, flake tools, 1 scraper, was found 200 yds. from east side of Willow Creek.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1969

BORDEN NO: EaPk 76 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL046535 LEGAL REF: NE.NE.22.13.28.4

SITE TYPE: Kill Site/Buried Campsite

LOCATION: 6 miles west and 5 miles north of Claresholm, 0.25 miles south and 100 yds. west of river cut.

DESCRIPTION: Firebroken rock and bone was observed on the edge, in the cutbank, of the first and second terrace on east side of Willow Creek.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 116 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL038536 LEGAL REF: NW.NE.22.13.28.4

SITE TYPE: Buried Campsite

LOCATION: 8 miles west and 2.5 miles south of Stavely, on west bank of Willow Creek.

DESCRIPTION: Firebroken rock and bone were noted in two levels - 0-30 cm and 100-120 cm below surface in a buried soil horizon. The upper level extends downstream several hundred yards while the lower one seems more restricted.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO:	EaPk 118	MAP REF:	82I/4 Claresholm
U.T.M.:		LEGAL REF:	NW.NW.22.13.28.4

SITE TYPE: Tipi Rings

LOCATION: 8 miles west and 2.5 miles south of Stavely on south side of Willow Creek.

DESCRIPTION: Eight tipi rings, 15 ft. across, were observed clustered close together. They are fairly well buried.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO:	EaPk 119	MAP REF:	82I/4 Claresholm
U.T.M.:	12UUL036535	LEGAL REF:	NE.NW.22.13.28.4

SITE TYPE: Tipi Rings

LOCATION: 8 miles west and 2.5 miles south of Stavely on prairie level to the southwest of Willow Creek valley.

DESCRIPTION: A single stone circle, approximately 20 ft. across. The ring has a single row of stones which are up to 1 ft. in diameter and tends to the rectangular rather than circular.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO:	EaPk 120	MAP REF:	82I/4 Claresholm
U.T.M.:	12UUL037534	LEGAL REF:	SE.NW.22.13.28.4

SITE TYPE: Tipi Rings

LOCATION: 8 miles west and 1 mile south of Stavely on prairie level on the west side of Willow Creek.

DESCRIPTION: Fifteen tipi rings, 15-20 ft. in diameter with variably sized (4 in. to 18 in.) rocks. Rings are moderately buried, in good condition and the rocks are place in a single line.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 121 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: NE.SW.21.13.28.4

SITE TYPE: Drive Lane

LOCATION: 5 miles west and 3.5 miles south of Stavely.

DESCRIPTION: Drive lane runs in a southwesterly direction. The cairns are 2-3 ft. in diameter with 5 ft. between cairns and medium lichen cover and deposition around the rocks.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1969

BORDEN NO: EaPk 122 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL047527 LEGAL REF: NE.SE.22.13.28.4

SITE TYPE: Tipi Rings/Stone Alignment

LOCATION: 4 miles south and 4.5 miles west of Stavely on west side of bluff.

DESCRIPTION: A central cairn (ca. 3 ft. in diameter, comprised of stones 1 ft. in diameter) with three radiating spokes up to 50 ft. in length.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 123 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL038536 LEGAL REF: NW.NE.22.13.28.4

SITE TYPE: Bison Kill

LOCATION: 8 miles west and 2.5 miles south of Stavely on a bend of Willow Creek.

DESCRIPTION: Bone appears in a cut at three depths: 0-40 cm., at 160-180 cm. and at 200-210 cm. The bone appears to be butchered in all levels. The cut is from 10-12 ft. in this area.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 124 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL040527 LEGAL REF: NW.SE.22.13.28.4

SITE TYPE: Rock Shelter (Campsite)

LOCATION: 8 miles west of Pulteney, south of EaPk 122. The site is on the south side of a tributary creek of Willow Creek entering on the west.

DESCRIPTION: A sandstone outcropping with an overhang of 5 ft. was associated with butchered and burnt bone. The shelter faces north and is 70 ft. long and 20 ft. high above a slump.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 125 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL042527 LEGAL REF: NW.SE.22.13.28.4

SITE TYPE: Bison Jump

LOCATION: 8 miles west of Pulteney. Site is on the south side of a tributary creek on the west side of Willow Creek, below prairie level, 20 ft. east of EaPk 124.

DESCRIPTION: A sandstone outcropping, abourt 70 ft. long and 20 ft. high, facing north. Butchered bison bone found in slump across the creek and also below the outcropping, within 1 ft. of the surface.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 126 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: NE.NW.15.13.28.4

SITE TYPE: Drive Lane

LOCATION: 8 miles west and 3 miles south of Stavely.

DESCRIPTION: A row of cairns, more or less on the west side of the crest of a ridge (highest seen from the road to the west). The cairns are very intermittent, 18 in. to 2 ft. in diameter with stones 4 in. to 18 in. across which are medium to well buried.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 127 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL036518 LEGAL REF: SE.NW.15.13.28.4

SITE TYPE: Cairns

LOCATION: 6 miles west of Pulteney and south of Willow Creek Park. The site is along the top of a small ridge on the prairie level. The cairns are possibly a continuation of EaPk 126.

DESCRIPTION: Three cairns, 3 ft. in diameter with rocks about 9 in. in diameter. The cairns are well buried and in a row.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 128 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL040515 LEGAL REF: NE.SW.15.13.28.4

SITE TYPE: Cairn

LOCATION: 8 miles west and 3 miles south of Stavely.

DESCRIPTION: A single cairn on top of a hill, south of a pond or slough. The cairn consists of about 12 rocks, is well buried and approximately 2.5 ft. in diameter.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 129 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL047527 LEGAL REF: NW.SW.23.13.28.4

SITE TYPE: Tipi Ring

LOCATION: 8 miles west and 3 miles south of Stavely, directly across from EaPk 73, on prairie level on the west side of Willow Creek.

DESCRIPTION: One tipi ring, 15 ft. in diameter. It is a single row of stones, fairly well buried but easily visible. The rocks are less than 1 ft. in diameter and there is a "hearth" in the center. 100 ft. south, another ring, same diameter, was found.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 130 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: SW.SE.22.13.28.4

SITE TYPE: Tipi Rings

LOCATION: 4.75 miles west and 0.5 miles north of Pulteney. The site is on prairie level south of a shallow coulee on the west side of Willow Creek.

DESCRIPTION: Three tipi rings in a slight depression.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 131 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL048525 LEGAL REF: SW.SW.23.13.28.4

SITE TYPE: Tipi Rings

LOCATION: 8 miles west and 3 miles south of Stavely on prairie level on the west side of Willow Creek.

DESCRIPTION: Two 'double stone' rings, 12- 15 ft. in diameter and comprised of rocks less than 1 ft. in diameter, were observed.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 132 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: SW.SW.23.12.28.4

SITE TYPE: Cairns

LOCATION: 8 miles west and 3 miles south of Stavely on west side of Willow Creek.

DESCRIPTION: One large potted cairn (10 ft. in diameter) and a smaller cairn (3.5 ft. in diameter), also potted, were observed.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 133 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL050520 LEGAL REF: ?. N½.14.13.28.4

SITE TYPE: Bison Jump

LOCATION: 5 miles west of Pulteney on prairie level on the west side of Willow Creek.

DESCRIPTION: Steep banks with rows of stones leading to precipice. Some bones present at the base. Stone drive lanes of undetermined length; large piles found near the edge.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: R. G. Forbis/Glenbow Foundation 1965

BORDEN NO: EaPk 134 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL050520 LEGAL REF: E½.NW.14.13.28.4

SITE TYPE: Drive Lanes

LOCATION: West of Stavely on prairie level on west side of Willow Creek.

DESCRIPTION: A 1 ft. to 3 ft. high cairn with a diameter of 1 - 6 ft., medium lichen cover, unknown but variable deposition around the rocks and variable distance between the rock piles. Some piles parallel to river.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 135 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: S½.NW.22.13.28.4

SITE TYPE: Drive Lanes

LOCATION: 8 miles west and 2.5 miles south of Stavely, south of Willow Creek Park.

DESCRIPTION: An undulating row of cairns, 7 - 12 ft. apart. The cairns are about 2 - 3 ft. across and consist of 4 - 12 in. rocks. Drive lane may be associated with EaPk 121 drive lanes.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 139 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL063475 LEGAL REF: SW.SW.1.13.28.4

SITE TYPE: Buried Campsite

LOCATION: 8 miles west and 4 miles south of Stavely on west side of Willow Creek.

DESCRIPTION: Firebroken rock and bone were noted in two levels in the cut bank of Willow Creek. The first is at 10 - 30 cm. and the lower occupation is 120 cm. below the surface.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 141 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL053516 LEGAL REF: SE.NW.14.13.28.4

SITE TYPE: Cairns

LOCATION: 8 miles west and 3 miles south of Stavely on prairie level on the west side of Willow Creek.

DESCRIPTION: A row of cairns, a few feet apart were observed on prairie level paralleling the river near an alkaline lake.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 169 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL061518 LEGAL REF: SE.NE.14.13.28.4

SITE TYPE: Buried Campsite

LOCATION: 4.5 miles west and 0.75 miles north of Pulteney above Willow Creek.

DESCRIPTION: Bone, firebroken rock, and a hearth were observed exposed approximately 3 ft. below the surface in a cutbank of Willow Creek.

CULTURAL AFFILIATIONS: Unknown/probably Middle Prehistoric

REFERENCES: University of Calgary Archaeological Survey 1969

SITE NO. 2, PINE COULEE

BORDEN NO: EaPk 2 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL020603 LEGAL REF: NW.NW.9.14.28.4

SITE TYPE: Rock Shelter

LOCATION: 5.25 miles west of Stavely, on sandstone outcroppings.

DESCRIPTION: Several small crevices in the sandstone outcropping on the northeast and east side of Table Butte.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1969

BORDEN NO: EaPk 23 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: NE.NE.28.13.28.4

SITE TYPE: Surface Hearth

LOCATION: The site is on prairie level, northeast of Willow Creek.

DESCRIPTION: Surface hearth on prairie level back from the valley wall. Also some firebroken rock was found in a cut on the valley wall, not deeply buried. Site is near cairn EaPa 81.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 37 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL030549 LEGAL REF: SE.NE.28.13.28.4

SITE TYPE: Drive Lanes

LOCATION: 8 miles west and 2 miles south of Stavely, on the hilltop below and north of a large rock outcropping, south of Willow Creek.

DESCRIPTION: Bifurcate row of cairns, 300 yds. long, averaging 2 ft. across, and with rocks generally less than 1 ft. in diameter. Site is likely associated with the buffalo jump, EaPk 111.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 39 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: NE.SE.28.13.28.4

SITE TYPE: Historic Structures/Rock Alignments

LOCATION: 8 miles west and 2 miles south of Stavely on the west side of Willow Creek.

DESCRIPTION: A couple of rectangular pit-like structures are set into side of hill. Sides are slumped and crockery and glass were found scattered near base of slope. Also near base of slope are several roughly parallel lines running N-S. These alignments may be badly disturbed cairns as some appear intact. They may also be historic, associated with the observed structures.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 77 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL044541 LEGAL REF: SW.NE.27.13.28.4

SITE TYPE: Cairn

LOCATION: 1 mile north and approximately 7 miles west of Pulteney on the east side Willow Creek. The site is on prairie level at the brow of a valley wall buttress, facing west.

DESCRIPTION: A large rock pile, 12 feet in diameter. Possibly this a farmer's pile, some parts are well buried so it could be a farmer's pile on top of the cairn. Stone up to 15 inches in diameter and lichen growth is widespread.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 78 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: E½.W½.27.13.28.4

SITE TYPE: Surface Site

LOCATION: On ploughed field, on prairie level on the east side of Willow Creek.

DESCRIPTION: Firebroken rock, quartzite flakes, some chert and petrified wood flakes and occasional bone fragments were found scattered on the surface.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 79 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: NE.NW.27.13.28.4

SITE TYPE: Surface Site

LOCATION: Site located west of Pulteney, overlooking Willow Creek, in field, on prairie level.

DESCRIPTION: Scattered firebroken rock, quartzite and chert flakes were found in wheat field and in road cut. Some firebroken rock buried 6 - 12 inches.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 80 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: NW.NW.27.13.28.4

SITE TYPE: Surface Site

LOCATION: North and west of Pulteney on second terrace about 30 feet down from prairie level and 15 feet above the creek.

DESCRIPTION: Scattered material including side-notched points reported along the fence line and near a chicken house. Scattered material--chert and siltstone--noted. Two possible tipi rings noted on a slightly lower terrace southewest of where the artifacts were found.

CULTURAL AFFILIATIONS: Late Prehistoric?

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 81 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: NE.NE.28.13.28.4

SITE TYPE: Cairn

LOCATION: Site is located on prairie level overlooking Willow Creek from the northeast.

DESCRIPTION: Cairn is 3 feet by 2 feet. Rocks are up to 9 inches in diameter. The cairn is quite deeply buried and covered with orange-coloured lichen. Site is near surface hearth EaPk 23.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 82 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: NE.SW.34.13.28.4

SITE TYPE: Tipi Rings

LOCATION: Southwest of Stavely on a glacial valley tributary to Willow Creek. Site is on unbroken land on a flat just below prairie level.

DESCRIPTION: A well buried ring 12 - 15 feet in diameter. The stones are up to 1 foot across. Two more rings located north towards the farmhouse.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 83 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: NE.SW.34.13.28.4

SITE TYPE: Cairns

LOCATION: Southwest of Stavely, on prairie level.

DESCRIPTION: Four cairns in a north-south line, roughly 50 yards (?) west from a fence. Cairns average 2 - 3 feet across, the stones are small and well buried. Tipi ring is located immediately north.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 84 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: SW.SE.27.13.28.4

SITE TYPE: Cairns

LOCATION: Southwest of Stavely on prairie level overlooking Willow Creek valley from the east. A small draw cuts past north of the site.

DESCRIPTION: Two adjacent rock piles approximately 8 feet across with stones up to 1 foot in diameter on the brow of the Willow Creek valley wall. Sandstone indicated from down the hill and some scatter of rock found down the hill.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 85 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: SE.SW.27.13.28.4

SITE TYPE: Sandstone Outcrops (Burials? Campsites?)

LOCATION: Southwest of Stavely and northwest of Pulteney, on Willow Creek. Site is at the base of a terrace intermediate between prairie level and river level.

DESCRIPTION: Crevices and overhangs all along the outcrops. Possible burials and rock shelters although no evidence of occupation was noted. Some firebroken rock found above.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 86 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: SW.SE.33.13.28.4

SITE TYPE: Tipi Rings

LOCATION: Southwest of Stavely. Site is on Willow Creek, on prairie level overlooking a deep valley to the west, tributary to Willow Creek.

DESCRIPTION: One good tipi ring, about 10 feet across, quite deeply buried. Two possible indistinct rings are associated.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 87 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: SW.SE.33.13.28.4

SITE TYPE: Campsite/Tipi Rings

LOCATION: Site is southwest of Stavely on east bank of Willow Creek. Site is on the second terrace (10 feet or so above river) which grades into the lower terrace (3 - 4 feet lower).

DESCRIPTION: Site includes remnants of tipi rings, partial circles, but they are badly disturbed by cattle and horses. Gophers and wind erosion have exposed a few bone fragments and firebroken rock. Material seem to have been buried 6 inches or so.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 88
MAP REF: 82I/4 Claresholm
U.T.M.: 12UUL
LEGAL REF: NE.SW.33.13.28.4
SITE TYPE: Cairn

LOCATION: The site is located southwest of Staveley, near the Provincial Park along Willow Creek.

DESCRIPTION: The cairn is 3 feet in diameter, well buried and is lichen covered. The size of the rocks varies from a few inches to 1 foot.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 89
MAP REF: 82I/4 Claresholm
U.T.M.: 12UUL
LEGAL REF: NE.SW.33.13.28.4
SITE TYPE: Tipi Ring

LOCATION: Southwest of Stavely along Willow Creek near Provincial Park #8.

DESCRIPTION: One large ring 20 feet in diameter. The rocks are widely spaced between the two branches of a tributary coulee to Willow Creek.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 90
MAP REF: 82I/4 Claresholm
U.T.M.: 12UUL
LEGAL REF: SE.SW.33.13.28.4
SITE TYPE: Tipi Ring

LOCATION: Southwest of Stavely, along the north bank of Willow Creek. Site is on prairie level overlooking the tributary coulee of Willow Creek near the southeast end.

DESCRIPTION: One tipi ring which is well buried with the rocks spread widely in a single circle, 12 - 15 feet in diameter.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 91 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: NW.NW.28.13.28.4

SITE TYPE: Campsite

LOCATION: The site is located on the crest of a hill overlooking Willow Creek northwest of Park boundary.

DESCRIPTION: Artifacts are in cutbank and some blowouts. There is a sharp slope down to the creek 100 feet with a small cut along the tip. Two occupations at less then 6 inches and at 1 foot.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 92 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: SE.NW.28.13.28.4

SITE TYPE: Tipi Ring/Campsite

LOCATION: Southwest of Stavely on the north side of Willow Creek Provincial Park #8, about 100 meters west of the bridge over Willow Creek. Camp is just west of bridge.

DESCRIPTION: A single large tipi ring, 6 - 7 meters in diameter. Sandstone forms most of the stones. 1971 visit a fireplace in the centre was noted. Had been marked for public with an information sign. Camp includes scatter of chert and quartzite flakes (depth probably less then 6 inches) and 1 point base found in old garden area surrounded by virgin prairie. Bone showing 6 inches below surface in cutbank of second terrace.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968; Alberta Provincial Parks Survey 1971.

BORDEN NO: EaPk 93 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL011560 LEGAL REF: NW.SE.32.13.28.4

SITE TYPE: Tipi Ring

LOCATION: Southwest of Stavely on the third terrace of Willow Creek.

DESCRIPTION: One good tipi ring, 15 feet in diameter and rocks up to 15 inches in diameter. Also 2 possible rings in the vicinity.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 94 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL008564 LEGAL REF: SW.NE.32.13.28.4

SITE TYPE: Surface Site

LOCATION: Southwest of Stavely on Willow Creek, on prairie level just southeast of a small gravel pit.

DESCRIPTION: Firebroken rock noted scattered on the surface.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 95 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL007568 LEGAL REF: SE.NW.32.13.28.4

SITE TYPE: Campsite

LOCATION: The site is on top of a hill, cut away on the west into Willow Creek (150 feet below).

DESCRIPTION: Firebroken rock is visibly present in the cut and some bone fragments were located in buried soil 2 feet beneath the surface. One chert flake was collected.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 96 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL000-03 569-72 LEGAL REF: N½.NW.32.13.28.4

SITE TYPE: Stone Circles/Cairns

LOCATION: The site is located approximately 2.5 kilometers south of the community of Stavely.

DESCRIPTION: Five stone features and four cairns were observed during mitigative studies. Cultural material was observed in gravel tests and rodent disturbances between these features. The estimated site size is 300 x 300 meters. Ten 1 x 1 meter units were excavated in Stone Circle No. 1. One hundred and fifty items were recovered from Stone Circle No. 1 and two cores and one biface were collected from other features.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968; Fedirchuk McCullough & Associates Ltd. 1984

BORDEN NO:	EaPk 103	MAP REF:	82I/4 Claresholm
U.T.M.:	12UUL004552	LEGAL REF:	NE.NW.29.13.28.4

SITE TYPE: Cairns

LOCATION: 2 miles south and 7.5 miles west of Stavely along the north side of a tributary valley (running east-west) to Willow Creek. The cairns are east of a small pond formed by a dam across the small stream in the valley.

DESCRIPTION: Two cairns which are 50 feet apart or so on the prairie level above the valley. To the north the field is ploughed so the cairns may be farmer's rock piles but they are small and fairly well buried. The diameter of the cairns is approximately 2.5 feet and the rocks are 8 inches across.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO:	EaPk 104	MAP REF:	82I/4 Claresholm
U.T.M.:	12UUL000554	LEGAL REF:	NW.NW.29.13.28.4

SITE TYPE: Cairn

LOCATION: 8 miles west and 2 miles south of Stavely along the tributary coulee to Willow Creek. The cairns are 100 yds. north of of a small pond.

DESCRIPTION: One cairn along the north side of the tributary valley to Willow Creek. It is well buried and approximately 2.5 ft. in diameter. 6 to 8 in. rocks compose the cairn. It could be a farmer's rock pile since fields nearby were ploughed in the past.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 105 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL001550 LEGAL REF: SW.NW.29.13.28.4

SITE TYPE: Cairn

LOCATION: 8 miles west and 1.5 miles south of Stavely at the tributary coulee to Willow Creek. The cairn is in a flat area.

DESCRIPTION: A small cairn, well buried, and situated on the highest knoll of the lower hill. It is 2.5 ft. in diameter and the rocks are of variable size - 3 to 8 in.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 106 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL004551 LEGAL REF: SE.NW.29.13.28.4

SITE TYPE: Rock Alignment

LOCATION: 8 miles west and 2 miles south of Stavely on a ridge on the south side of the tributary coulee to Willow Creek (west side).

DESCRIPTION: A row of small cairns running west. The cairns are 1 - 1.5 ft. in diameter and composed of a half dozen rocks each. A 3.5 ft. cairn was found 100 yds. east in a slightly low area at the bottom.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 107 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL021547 LEGAL REF: NE.SW.28.13.28.4

SITE TYPE: Rock Alignment/Tipi Rings

LOCATION: Site is approximately 8 miles west and 2 miles south of Stavely on the southwest side of Willow Creek Provincial Park near south entrance of Park.

DESCRIPTION: A tipi ring, 4 meters in diameter and, is located 10-15 meters northeast of Park sign. South of ring are two rock alignments. One rock line runs E-W extending from end of fence line. Line is very wide. Other line runs SW-NE, is less clear (more buried) and is possibly along ploughed field. Three additional tipi rings were observed and more, disturbed by cattle, may be present.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968; E. Gryba 1971

BORDEN NO: EaPk 108 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL024550 LEGAL REF: SW.NE.28.13.28.4

SITE TYPE: Tipi Rings and Cairns

LOCATION: 8 miles west and 2 miles south of Stavely, south of Willow Creek Park.

DESCRIPTION: Four possible cairns and 3 tipi rings. There may be more which are disturbed because there are many other rocks lying around. The site is on prairie level overlooking Willow Creek is to the northeast.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 109 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL026553 LEGAL REF: NW.NE.28.13.28.4

SITE TYPE: Bison Kill and Campsite

LOCATION: 8 miles west of Stavely, just southeast of Willow Creek Park across fields on south side of river. The site is on the third terrace in the cutbank.

DESCRIPTION: A stratified bison kill. Bones (butchered) are visible in the bank from 2 - 6 feet down, firebroken rock noted at about 1 foot and 1 flake collected at 8 inches. Localized burns noted at several levels. Bones extend the full length of the cut.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 110 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: NW.SW.27.13.28.4

SITE TYPE: Buried Campsite

LOCATION: 8 miles west of Stavely, on west bank of Willow Creek.

DESCRIPTION: Three occupations found on the flat on the west side of Willow Creek - 150 or more feet deep before the rise. (1) 20 - 30 cm some small bone fragments, (2) 40 - 50 cm 1 buffalo skull and bone fragments, and (3) 140 cn 1 distal lumbar vertebrae. Occupations found in cutbank (west side and firebroken rock seen in slump.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 111 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL028-31 550-51 LEGAL REF: SW.NE.28.13.28.4

SITE TYPE: Buffalo Jump

LOCATION: 2.5 miles south and 7 miles west of Stavely on west bank (lowest terrace) of Willow Creek. Site is 100 yards downstream from north end of old river channel along cutbank of present Willow Creek channel.

DESCRIPTION: Bone is washing out of bank and lying in river gravels. Shovel cut showed the main deposit to be 140 cm below surface. Deposit is 8 inches thick, solid bone and lightly butchered bone with not much breakage. A few bone fragments appear higher in the profile as well. Sharp tallus slope from prairie level to river channel marks possible continuation of jump area. A few bone fragments were noted in a small cut in bank.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 112 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: SW.SW.27.13.28.4

SITE TYPE: Cairn

LOCATION: 8 miles west of Stavely and south of Willow Creek Park.

DESCRIPTION: One cairn with one large rock (2 feet x 18 inches) in the center and other rocks about 12 inches in diameter scattered closely around. The site is fairly recent. There is little lichen growth or burial.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 113 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: SW.SW.27.13.28.4

SITE TYPE: Tipi Rings

LOCATION: 8 miles west of Stavely, south of Willow Creek Park. The site is down the side of a hill on a flat in the coulee, on the northeast side of the coulee.

DESCRIPTION: Seven rings, 6 of which were about 20 feet in diameter and 1 which was about 12 feet in diameter. They all looked to be the same age and are moderately buried. The sizes of the rocks were varied, from 4 inches to 12 inches or larger.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 114 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: NE.SE.28.13.28.4

SITE TYPE: Tipi Rings

LOCATION: 8 miles west and 2 miles south of Stavely, on the brow of an east facing hill overlooking Willow Creek from the west and across the lower terraces. Tipi rings located on a terrace below prairie level.

DESCRIPTION: Twelve rings which are approximately 15 feet across. The rocks are variable in size, about 1 foot across. Site is in same general area as EaPk 39.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 115 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: NE.SE.28.13.28.4

SITE TYPE: Rock Alignment

LOCATION: 8 miles west and 2 miles south of Stavely, on a flat terrace north of a large bedrock outcropping, south of Willow Creek and well above the river level.

DESCRIPTION: An irregular line or set of lines (single row) meandering around the flat, reported to be a buffalo effigy.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 117 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL LEGAL REF: SW.SW.27.13.28.4

SITE TYPE: Rock Alignment

LOCATION: 8 miles west and 2.5 miles south of Stavely, in a small tributary coulee below prairie level.

DESCRIPTION: A backwards "L" shaped rock line, about 15 feet long north - south and 10 feet east-west. The rocks are up to 15 inches across.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 172 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL011559 LEGAL REF: N½.SE.32.13.28.4

SITE TYPE: Campsite

LOCATION: Drive west of Stavely on S.R. 527. Site is just east of Willow Creek on the south side of the road.

DESCRIPTION: Several flakes, bone fragments, pieces of firebroken rock and ceramic fragments were located in shovel tests.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: Aresco Ltd. 84-72

BORDEN NO: EaPk 173 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL010560 LEGAL REF: NW.SE.32.13.28.4

SITE TYPE: Stone Circle/Lithic Scatter

LOCATION: Drive west of Stavely on S.R. 527. Site is just east of Willow Creek on the north side of the road.

DESCRIPTION: Site consists of a stone circle which is partially buried and somewhat scattered. Numerous flakes, cores, bone fragments, and pieces of firebroken rock were observed in rodent burrows.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: Aresco Ltd. 84-72

BORDEN NO: EaPk 175 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL033572 LEGAL REF: SW.SW.3.14.28.4

SITE TYPE: Small Lithic Scatter

LOCATION: Drive west of Stavely on S.R. 527.

DESCRIPTION: A quartzite core, two quartzite flakes, and a piece of firebroken rock were observed in a fallow field.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: Aresco Ltd. 84-72

BORDEN NO: EaPk 176 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL032582 LEGAL REF: SE.NE.4.14.28.4

SITE TYPE: Lithic Scatter

LOCATION: Drive west of Stavely on S.R. 527.

DESCRIPTION: A quartzite core and four flakes were observed in a fallow field.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: Aresco Ltd. 84-72

BORDEN NO: EbPk 4 MAP REF: 82I/4 Claresholm

U.T.M.: 12UUL02 67 LEGAL REF: SE.SW.3.15.28.4

SITE TYPE: Buffalo Kill

LOCATION: Go 2 miles south of Parkland, turn west for a distance of about 5 miles west side of Pine Coulee.

DESCRIPTION: Spring about half way up the slope. Steep slope with some sandstone cliffs near the top. About 100 feet high. Bone is indurated in clay-like slope. Bone exposure is very small and deep. Gathering basin (to the SW is classic) but no stone piles. Bone is very solid and cemented into the matrix.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: R. G. Forbis/Glenbow Foundation 1963

BORDEN NO: EbPk 6 MAP REF: 82I/4 Claresholm
U.T.M.: 12UUL02 69 LEGAL REF: NW.SE.10.15.28.4
SITE TYPE: Petrographs
LOCATION: In Pine Coulee on the north bank.

DESCRIPTION: Natural cave has been built up by white men, see Dewdney report on this site. Petroglyphs on walls of the cave.

CULTURAL AFFILIATIONS: Unknown
REFERENCES: D. R. King/Glenbow Foundation Study 1965

BORDEN NO: EbPk 8 MAP REF: 82I/4 Claresholm
U.T.M.: 12UUL02 62 LEGAL REF: SW.SW.21.14.28.4
SITE TYPE: Depression

LOCATION: Go west of Stavely for 6.5 miles to Table Butte. Circular depression on High Point at north end of Alkaline Lake.

DESCRIPTION: A six foot diameter depression in the top of the hill, marked by a luxurious growth of very high grasses.

CULTURAL AFFILIATIONS: Unknown
REFERENCES: University of Calgary Archaeological Study 1968

BORDEN NO: EdPk 174 MAP REF: 82I/4 Claresholm
U.T.M.: 12UUL017565 LEGAL REF: SW.NE.33.13.28.4
SITE TYPE: Isolated Find

LOCATION: Drive west of Stavely on S.R. 527 to about 1 kilometer east of Willow Creek, just north of the proposed road.

DESCRIPTION: A quartzite core was observed north of the proposed right-of-way on a high ridge.

CULTURAL AFFILIATIONS: Unknown
REFERENCES: Aresco Ltd. 84-72

BORDEN NO:	EaPk 102	MAP REF:	82I/4 Claresholm
U.T.M.:	12UTL996564	LEGAL REF:	SE.NE.31.13.28.4

SITE TYPE: Campsite

LOCATION: 1 mile south and ca. 10 miles west of Stavely on Willow Creek. Cross creek, go up hill and along coulee tops to road leading into valley with old farm buildings. Site is near buildings on a 10 ft. high river terrace.

DESCRIPTION: A few bone fragments (1 jaw fragment of a dog included) noted in the backdirt of gophers. Also, bones were noted west of an old building site marked by sandstone slabs in a rectangular pattern which is west of the standing log buildings.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

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* For remaining sites in Site No. 4, Pine Coulee/Willow Creek, please refer to Appendix II.

BORDEN NO: EaPk 98 MAP REF: 82I/4 Claresholm

U.T.M.: 12UTL994575 LEGAL REF: SW.SE.6.14.28.4

SITE TYPE: Surface Campsite

LOCATION: 1 mile west of Stavely, near Willow Creek.

DESCRIPTION: No data.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 99 MAP REF: 82I/4 Claresholm

U.T.M.: 12UTL994567 LEGAL REF: SW.NE.31.13.28.4

SITE TYPE: Cairns

LOCATION: 1 mile south and 8 miles west of Stavely in farmyard. Cross stream and go up the hill and then along coulee tops overlooking the valley with buildings on it until cairn is found.

DESCRIPTION: The cairn on the side of the coulee is 3.5 ft. in diameter and generally semi-circular in shape. The cairn is probably a farmer's rock pile, but it is old because it is well buried and lichen covered. Two more cairns, located several hundred yards west of the main cairn, consist of large (6 in. to 1 ft. diameter) rocks. One cairn is near the edge of the ploughed field and the other is near the dump cut.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968

BORDEN NO: EaPk 100 MAP REF: 82I/4 Claresholm

U.T.M.: 12UTL994564 LEGAL REF: SW.NE.31.13.28.4

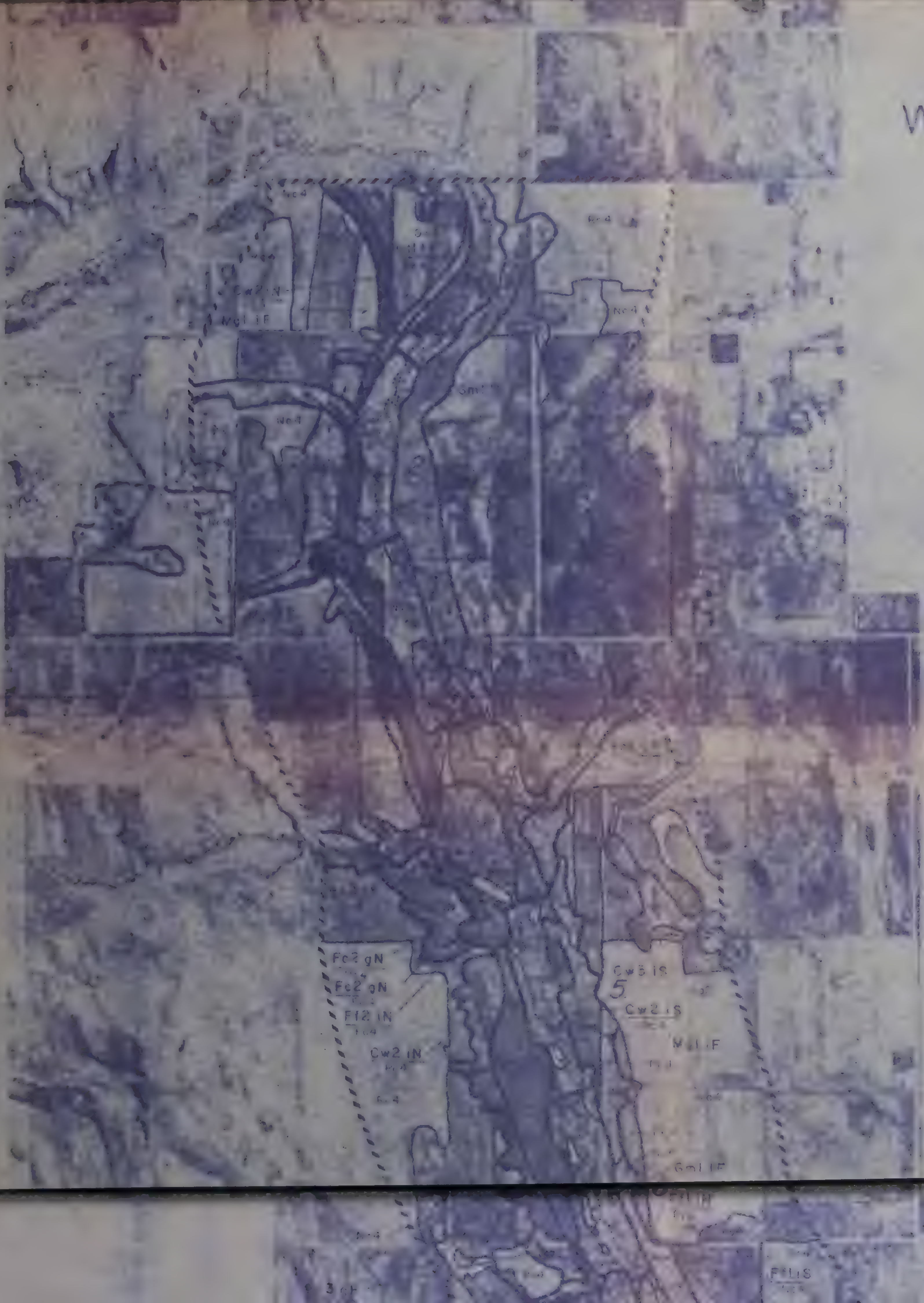
SITE TYPE: Buried Campsite

LOCATION: 1 mile south and 8 miles west of Stavely in farmyard. Cross stream and go up the hill and then along the coulee tops to road leading into valley with old farm buildings. The site is near the buildings on second or third terrace, 30-40 ft. above Willow Creek.

DESCRIPTION: Site found in a cut at a depth of 1-2 ft. A hearth showing at the 2 ft. depth with fine reddened earth. Large rocks are present in the hearth and they appear in the river cut as well.

CULTURAL AFFILIATIONS: Unknown

REFERENCES: University of Calgary Archaeological Survey 1968



WILLOW CREEK RESERVOIR STUDY

Potential Site 2 – Pine Coulee

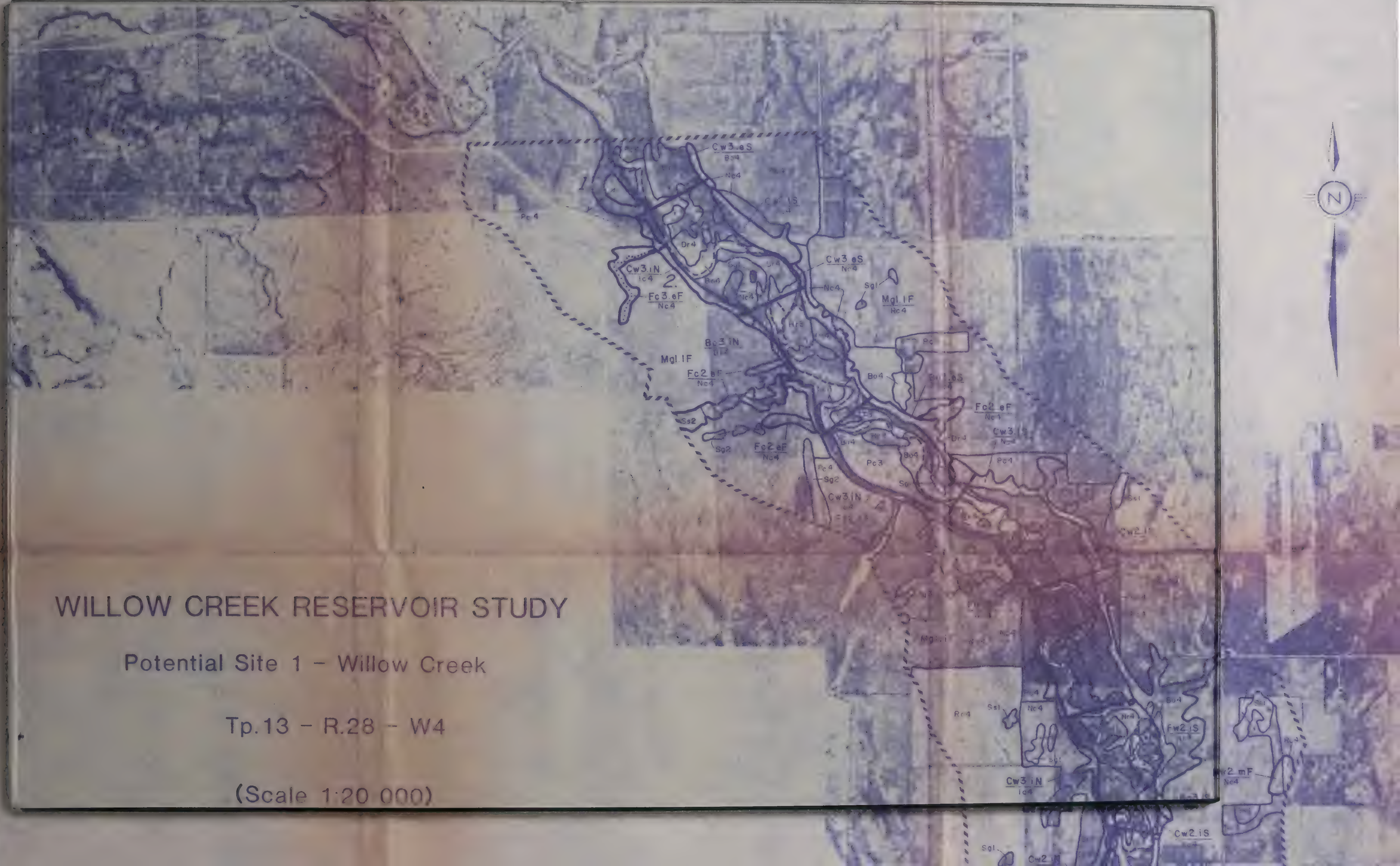
Potential Site 4– Pine Coulee/Willow Creek

Tp. 13, 14, 15 – R. 28 – W4

(Scale 1:20 000)

5
Fl2 IN
Cw2 IN
Mgl IF
Fl1 IN
Fl1 IS
3 gF
Mgl IF
Fc3 gF
Fc3 gF
Cw2 IN
8
Mgl IF
6

Fc2.cF
a
w3.eS
Ws
Fc2.cF
13
13



WILLOW CREEK RESERVOIR STUDY

Potential Site 1 – Willow Creek

Tp.13 – R.28 – W4

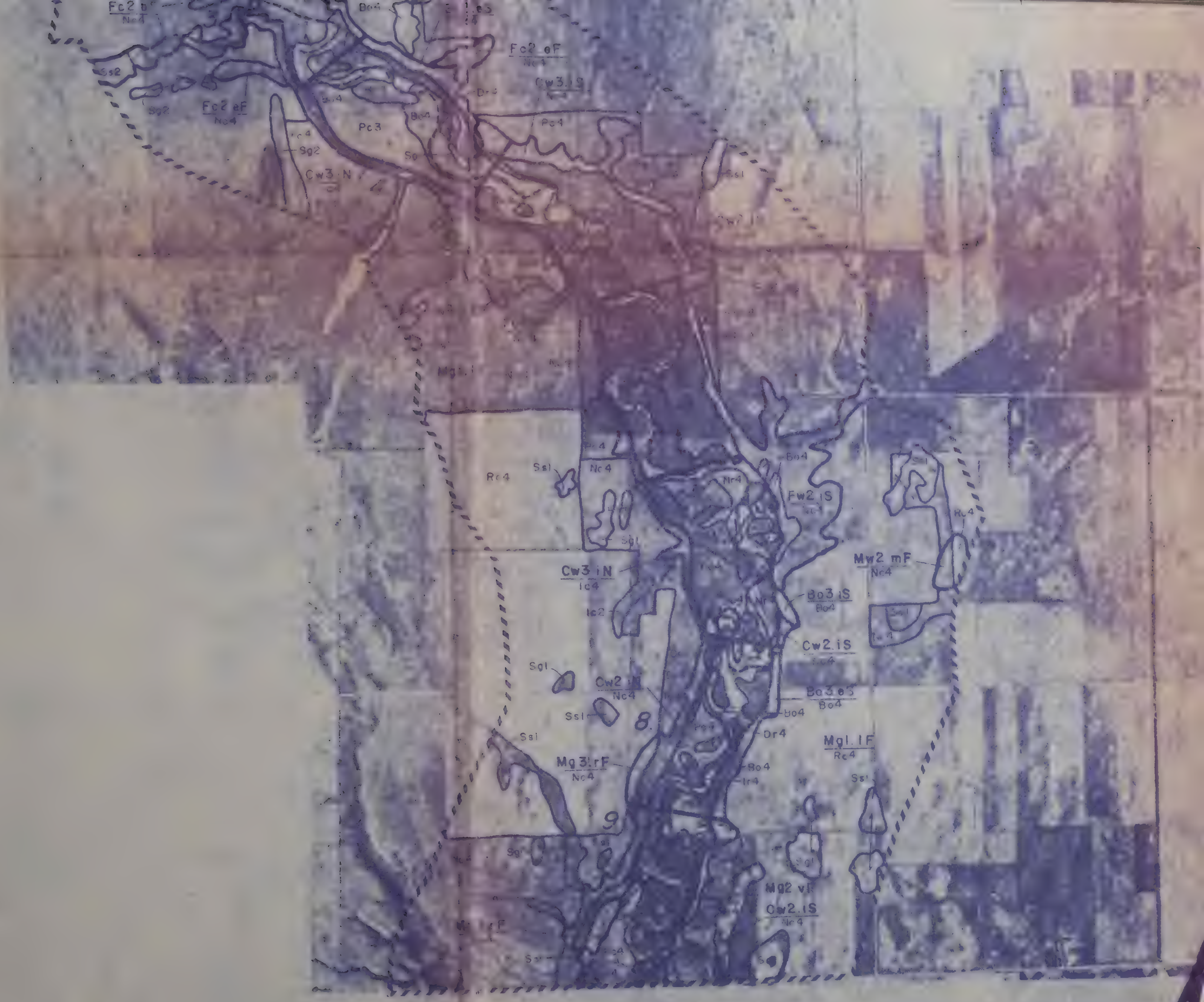
(Scale 1:20 000)

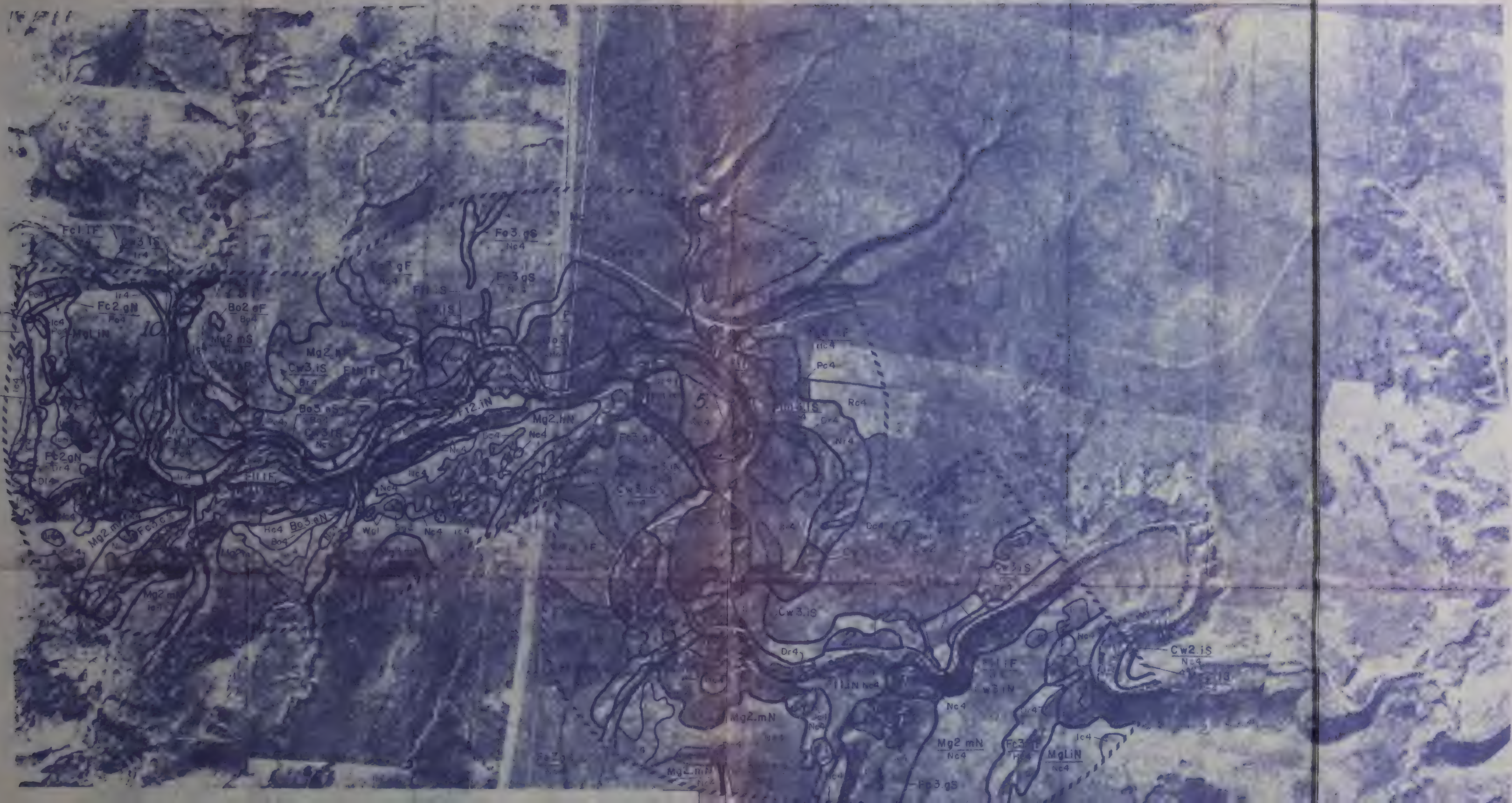
RESERVOIR STUDY

1 - Willow Creek

3 - R.28 - W4

ale 1:20 000)

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Cw3.iS
Ir4
Fo3.gS
Nc4
Fc3.gF
Nc4
Fc3.gS
Nc4
Fl1.iS
Cw3.iS
Dc4
Cw3.iS
Fc2.gN
Pc4
Ic4
Mg1.iN
10.
Bo2.eF
Bo4
Mg2.mS
Mg2.mF
Cw3.iS
Br4
Fl1.iF
Bo3.eN
Bo4
Bo3.eS
Bo4
Cw3.iS
Nc4
Fl2.iN
Mg2.hN
Dc4
Nc4
Fl1.iN
Pc4
Fc2.gN
Dr4
Dl4
Fl1.iF
Nc4
Hc4
Bo3.eN
Bo4
Wg1
Nc4
Ic4
Mg2.mN
Mg2.mN
Ic4
5.
Pc4
Rc4
Dr4
Nr4
Cw3.iS
Nc4
Dc4
Cw3.iS
Cw3.iS
Dr4
Fl1.iF
Fl1.iN Nc4
Cw3.iN
Nc4
Mg2.mN
Mg2.mN
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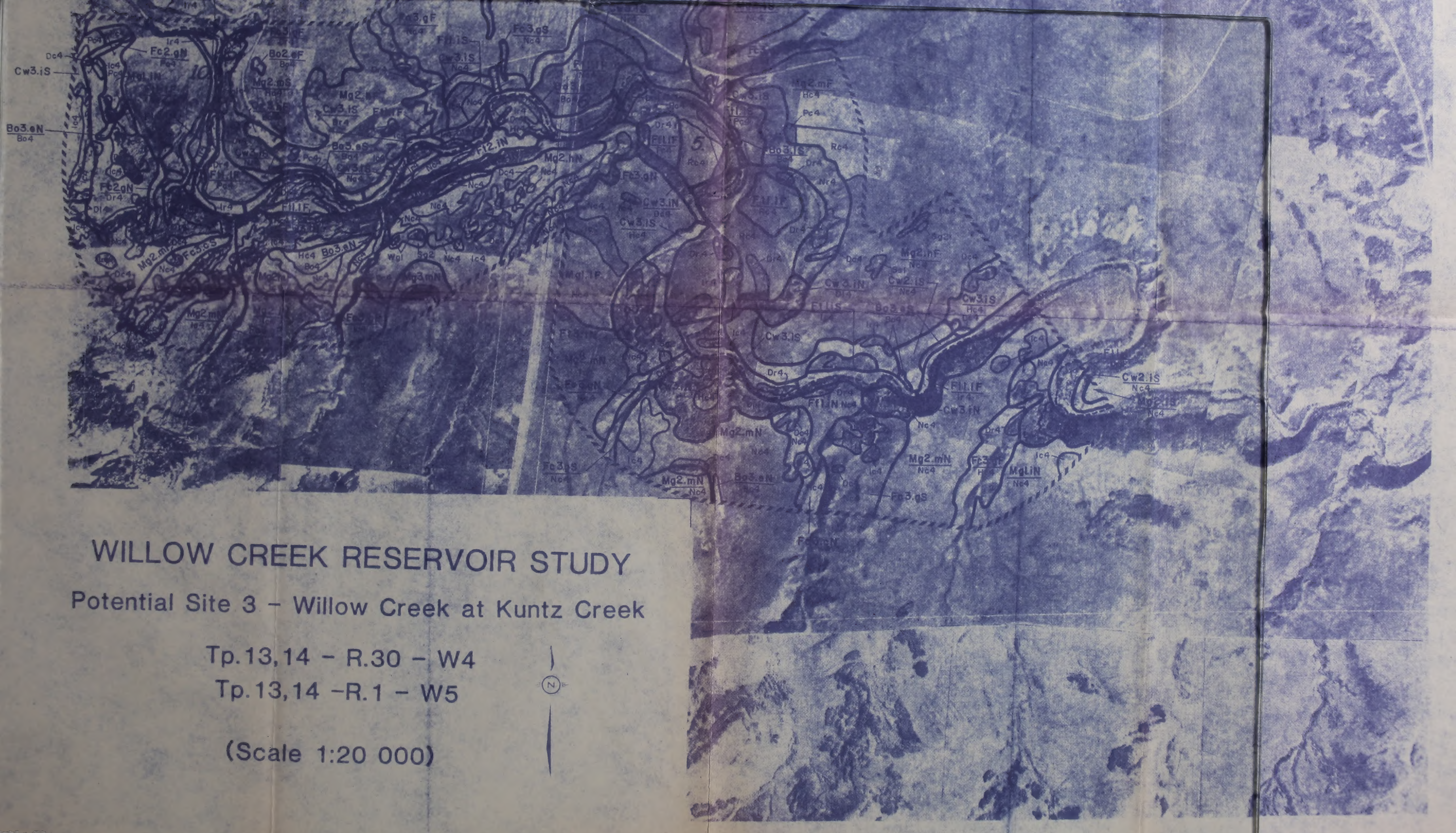

WILLOW CREEK RESERVOIR STUDY

Potential Site 3 - Willow Creek at Kuntz Creek

Tp.13,14 - R.30 - W4
Tp.13,14 -R.1 - W5

(Scale 1:20 000)

N.L.C. - B.N.C.
3 3286 07294869 4